FLOOD INUNDATION MODELLING USING MILHY

Final Technical Report

by

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User Manual

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<u>**VOLUME 2**</u>

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Preface

This is the user manual for the computer simulation model MILHY3. The volume should contain all the information a potential user requires to establish the data sets and run MILHY3. In addition, it provides detailed program information and the computer code. A basic review of the MILHY suite is provided and some guidelines on the selection of process are included. Detailed information on the development and validation of MILHY3 is contained within Volume 1 of this report.

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MILHY3 - Model Details

1.1 MILHY3

(cont) It

MILHY contains a number of hydrological and model control procedures. Conveniently, each of these is contained within the program implementation in a separate subroutine.

The structure of the MILHY program (Williams and Hann, 1972, 1973) is outlined in figure 1.1.

Hydrological procedures (indicated in the lower row of figure 1.1) are invoked to generate the outflow hydrograph for a subcatchment area, to perform routing calculations through channels and reservoirs, and to calculate sediment yield. Model control procedures are used to instruct the program to begin, to store a measured hydrograph, travel time table, or rating curve, to add two hydrographs together, to provide hard copies of printed or plotted information, and to perform error analyses on hydrograph predictions; and to finish.

As modelling begins at the most upstream subcatchment, and proceeds downstream by cumulating hydrographs, it is not necessary to store all of the information which is generated. At any one time, the program stores up to six hydrographs and six rating curves in core memory.

The hydrological and model control procedures will now be examined in more detail.

Keywords: Floods/forecasting/models; Channels/waterways/routing; Channel flow; Flow rate; Computerized simulation; Hydrography; Hydraulics/gradients/conductivity; Drainage; Runoff/travel time; Saturated soils; Mathematical models; Soils/porosity; Hydrology; Computer programs; Great Britain.

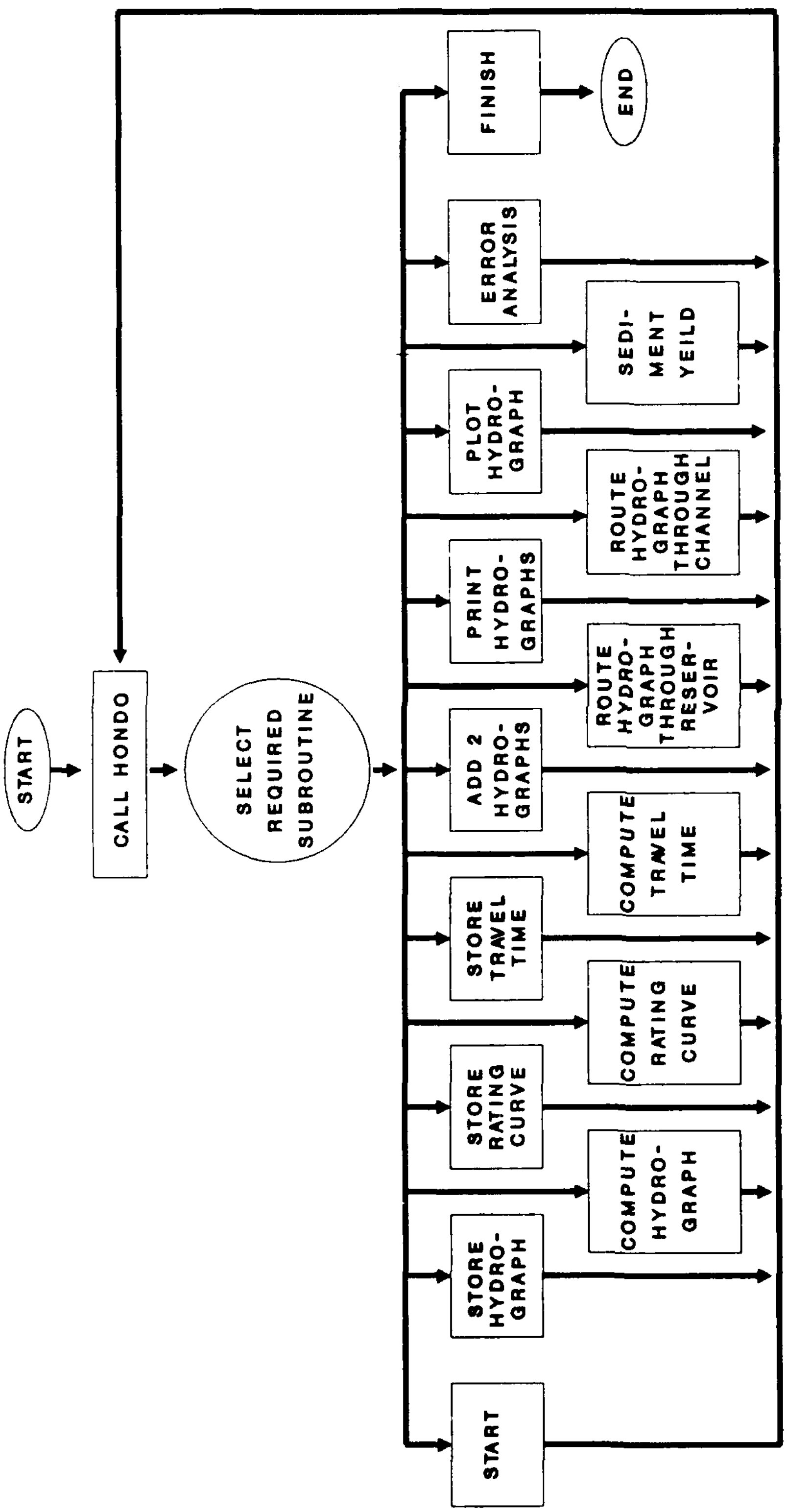

Figure 1.1
Hydrological and Control Commands for the MILHY3 Scheme

Chapter 1

1.1.1 Hydrological Procedures

There are four hydrological procedures in MILHY. (The compute rating curve, compute travel time, and route hydrograph through channel subroutines combine to form the flood routing hydrological procedure). It should be noted that all parameter units in this subsection are in imperial units.

Hydrograph Computation

A standard three stage procedure is used to generate the storm hydrograph for each subcatchment. Firstly, a unit hydrograph is derived synthetically for each subcatchment area from its physical characteristics. Secondly, direct or surface runoff is determined from either an empirically-based curve number routine, or a physically-based infiltration model (Anderson, 1982; Anderson and Howes, 1984), and, thirdly, these are convolved to produce the flood hydrograph for the subcatchment.

A dimensionless unit hydrograph method is used by MILHY. This has been synthesized from measured hydrographs from 34 catchments in Texas, Oklahoma, Arkansas, Louisiana, Mississippi, and Tennessee. These catchments range up to 16 square km in area. The synthesized dimensionless unit hydrograph (figure 1.2A) is described by a two parameter gamma distribution. For the beginning of the discharge rise (t=0) to the inflection point (t_0), discharge is given by:

$$u_t = u_p\ (t/t_p)^{(n-1)} e^{(1-n)(t/t\ -1)} \qquad (1.1)$$

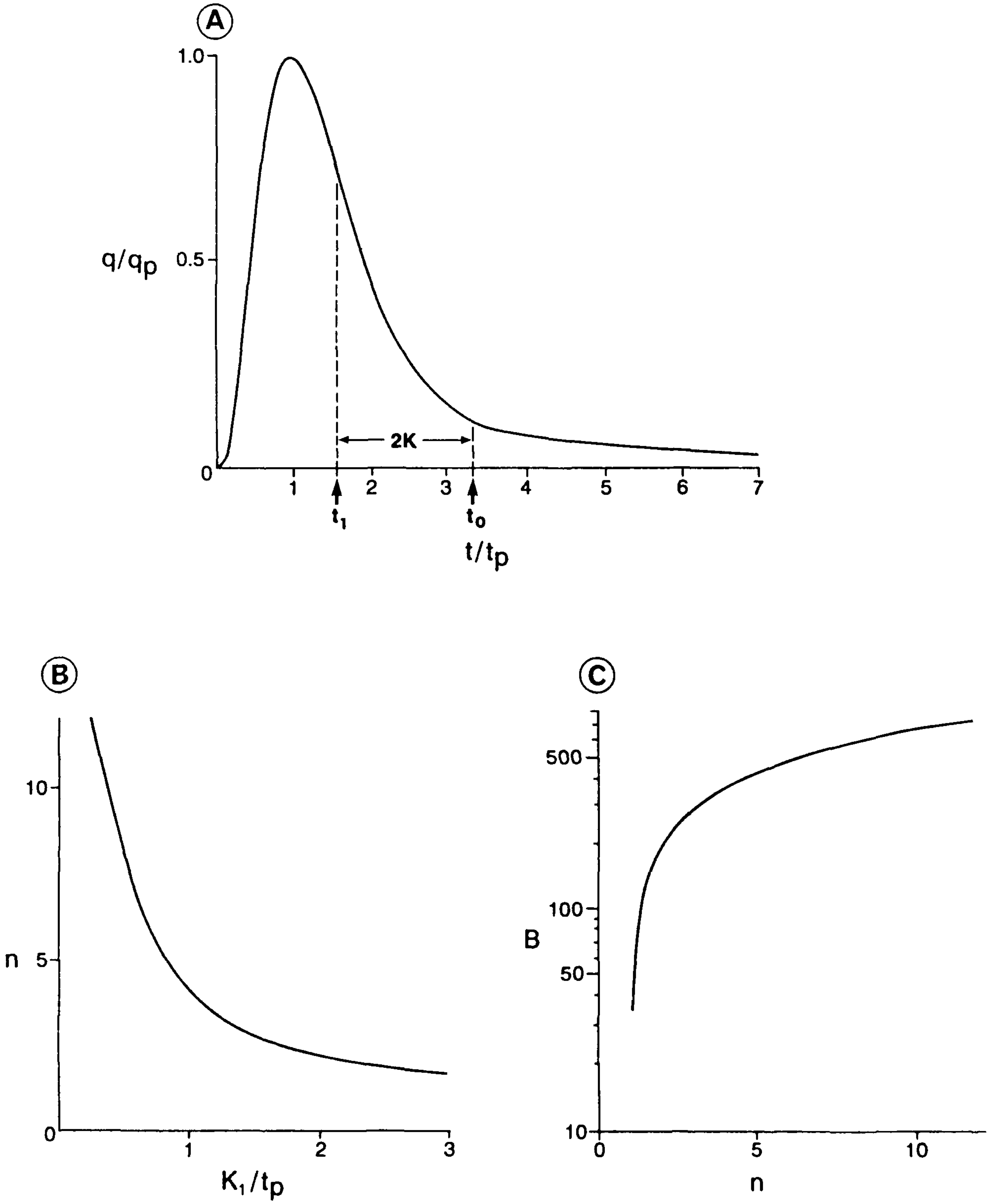

Figure 1.2
Generation of the Unit Hydrograph for MILHY3
(after Williams and Hann, 1973)

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Where:

u_t - unit hydrograph discharge at time t (ft^3s^{-1})
u_p - unit hydrograph peak discharge (ft^3s^{-1})
t_p - time to peak (hours)
n - dimensionless parameter
(a function of k_1/t_p, figure 1.2B)
k_1 - the first recession constant

For t_0 to t_1, where

$$t_1 = t_0 + 2k_1 \tag{1.2}$$

the recession depletion equation becomes:

$$u_t = u_0 e^{((t_0 - t)/k_1)} \tag{1.3}$$

Where:

t_0 - time at inflection point (hours)
u_0 - unit hydrograph discharge at inflection point (ft s^{-1})

Finally, for t_1 to infinity, the recession depletion equation becomes:

$$u_t = u_1 e^{((t_1 - t)/k_2)} \tag{1.4}$$

Where:

k_2 - the second recession coefficient $k_2 = 3k_1$
u_1 - unit hydrograph discharge at t_1 (ft^3s^{-1})

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The actual catchment unit hydrograph associated with a particular storm event can be derived from this dimensionless hydrograph, provided that information for the peak discharge (u_p), the time to peak discharge (t_p) and the recession constant (k_1) can be provided. Where, for the ungauged catchment, these data are not available, the following relationships may be used which relate the three characteristics to measurable basin properties such as catchment area, length of main channel, and elevation difference, features which can be derived from a topographic map:

$$u_p = \frac{BAQ}{t_p} \qquad (1.5)$$

Where:

B - dimensionless watershed parameter, a function of n (figure 1.2C)

A - watershed area (miles^2)

Q - total storm runoff (inches)

$$k_1 = 27.0(A)^{0.231}(SLP)^{-0.777}(L/W)^{0.124} \qquad (1.6)$$

Where:

SLP - elevation difference (feet) between catchment outlet and most distant point, divided by main channel length (miles)

L/W - watershed length, width ratio

$$t_p = 4.63(A)^{0.422}(SLP)^{-0.46}(L/W)^{0.133} \qquad (1.7)$$

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Catchment incremental is derived using either on empirically based Curve Number routine (USDA SCS, 1972), or physically-based infiltration algorithm (Anderson, 1982), described in section 1.2.

In the Curve Number procedure rainfall, runoff and storage are related in the following manner:

$$\frac{P - Q}{S'} = \frac{Q}{P} \tag{1.8}$$

where: P = total precipitation

S' = potential maximum storage

Q = actual runoff

This solution is simplified by emitting rainfall losses prior to the soil surface, giving a final solution for Q of:

$$Q = \frac{(P - I_a)^2}{P - I_a + S} \tag{1.9}$$

where: I_a = initial abstraction

S = $S' + I_a$

The relationship between I_a and S has been empirically derived by the SCS, and it is approximately:

$$I_a = 0.2S \tag{1.10}$$

Substituting this relationship into equation 1.9 gives

$$Q = \frac{(P - 0.2S)^2}{P + 0.8S} \qquad \text{for } P > 0.2S \tag{1.11}$$

To apply equation 1.11, S is transformed by the following equation:

$$S = \frac{1000}{CN} - 10 \tag{1.12}$$

where: $CN = 0$ when $S \rightarrow \infty$

$CN = 100$ when $S = 0$

The value of CN for a catchment is usually derived from field or map surveys and the appropriate USDA tables. It represents the net effects of soil type, land use, hydrologic soil group, and the antecedent soil moisture condition.

Finally, the incremental runoff and unit hydrograph are convolved to form the outflow discharge hydrograph according to the following relationship:

$$q_t = \sum_{t=2}^{n} (r_t u_{(n-t)}) \qquad \text{For } n > 2 \qquad 1.13$$

where:

n - number of time intervals of hydrograph

q_t - flood hydrograph discharge at time t ($ft^3 s^{-1}$)

r_t - runoff at time t (inches)

Channel Flood Routing

To perform channel flood routing, the user invokes the compute rating curve, compute travel time, and route hydrograph through channel subroutines.

A revised version of the Variable Storage Coefficient method has been incorporated into MILHY. This represents a compromise between very simple storage models and those methods based on the principles of hydraulics.

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Williams (1969) presents the Variable Storage Coefficient method, and provides a solution for it. In comparison to basic storage routing models, this method is considered to be a better approximation to reality as it does allow the storage coefficient and travel time to vary with river stage. It is considered to be reliable for a range of river flow conditions and reach lengths, and may be applied to routing of both channel and flood plain flows.

Application of this method requires a relationship between stage, end area, and discharge to be defined for the particular reach. If a measured relationship is not available, it can be derived by application of the Mannings equation, which is simple, easy to use, and not too demanding in terms of data. Discharge (q) is given by the following equation:

$$q = \frac{1.486}{n} \left(aR^{2/3} Sl^{1/2} \right) \qquad 1.14$$

Where:

- n - Mannings coefficient of roughness
- a - cross section area (ft^2)
- R - hydraulic radius (ft)
- Sl - slope of energy gradient

Twenty values on the rating curve are established by MILHY.

Given the inflow hydrograph for a reach with discharge values at equal time intervals, the outflow hydrograph can be calculated from the following equations. As a variable storage coefficient and travel time are assumed, these equations are recalculated for each discharge:

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$$O_{t+\Delta t} = C_{t+\Delta t}[I+((1/C_t) - 1)O_t] \qquad 1.15$$

$$C_{t+\Delta t} = \frac{2\ \Delta t}{2T_{t+\Delta t} + \Delta t} \qquad 1.16$$

$$C_t = \frac{2\ \Delta t}{2T_t + \Delta t} \qquad 1.17$$

$$T_t = \left(\frac{L}{1800(Vi_t + Vo_t)}\right)\left(\frac{(L)\ (SLP_0)}{(L)(SLP_0)+Di_t-Do_t}\right)^{1/2} \qquad 1.18$$

$$T_{t+\Delta t} = \left(\frac{L}{1800(Vi_{t+\Delta t}+Vo_{t+\Delta t})}\right)\left(\frac{(L)SLP_0}{(L)(SLP_0)+ Di_{t+\Delta t}-Do_{t+\Delta t}}\right)^{1/2} \qquad 1.19$$

Where:

I_t - inflow discharge at time t (ft^3s^{-1})

O - outflow discharge at time t (ft^3s^{-1})

I - average inflow discharge during time interval t (ft^3s^{-1})

$$I = \frac{I_t + I_{t+\Delta t}}{2}$$

C - storage coefficient for particular discharge

T - travel time for particular discharge (hrs)

L - reach length (ft)

Vi - velocity of inflow at time t (discharge divided by end area) ($ft\ s^{-1}$)

Vo - velocity of outflow at time t ($ft\ s^{-1}$)

SLP_0 - normal slope

Di - depth of inflow at time t (ft)

Do - depth of outflow at time t (ft)

Δt - time interval, constant throughout (hrs)

The solution for these equations is iterative, but no convergence problems have been experienced.

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In the latest model version, MILHY3, the channel routing routine has been further developed to incorporate the effects of out-of-bank flows. A full description of the development and validation of these new routines is given in Volume I of this report. The impact of momentum exchange between the main channel and floodplain flow segments has been incorporated during the development of the rating curve. Four techniques are proposed, each of which incorporates a differing position and length of an imaginary shear interface across which momentum exchange takes place. The four techniques are defined in Table 1.1, and the parameters defined on Figure 1.3.

In addition to momentum exchange, multiple routing reaches have been incorporated, which allow the separate routing of channel and floodplain flows downstream. This is particularly useful where the main channel is very sinuous and floodplain flows take a more direct path downstream, or where channel and floodplain boundary roughness values are widely different.

Reservoir Routing

The Storage Indication method is used to route hydrographs through reservoirs (USDA SCS, 1972). This uses the relation:

$$O_{t+\Delta t}=2(I +(S_t/\Delta t)-(S_{t+\Delta t}/\Delta t))-O_t \qquad 1.20$$

This method requires that a storage discharge relationship be specified for the reservoir.

Sediment Yield

The Universal Soil Loss equation, modified to allow sediment yield to be calculated for the individual storm, was incorporated into MILHY. This relation is given by:

$$Sy = 95.0[(q_p)(R)]^{0.56}(E)(Cr)(Pr)(LS) \qquad 1.21$$

Table 1.1

Alternative geometric definitions to incorporate segment interactions
(after Knight and Hamed, 1984)

Method	Flood Plain		Main Channel	
	Area	Wetted Perimeter	Area	Wetted Perimeter
1	(H-h) (B-b)	B-b + H-h	2bH	2b + 2h
2	(H-h) (B-b)	B-b + 2(H-h)	2bH	2b + 2H
3	(H-h) (B-b/2)	B-b + H-h	b(H+h)	2b + 2h
4	(H-h) (B-b/2)	B-b + H-h	b(H+h)	$2b + 2h + 2((H-h)^2+b^2)^{1/2}$

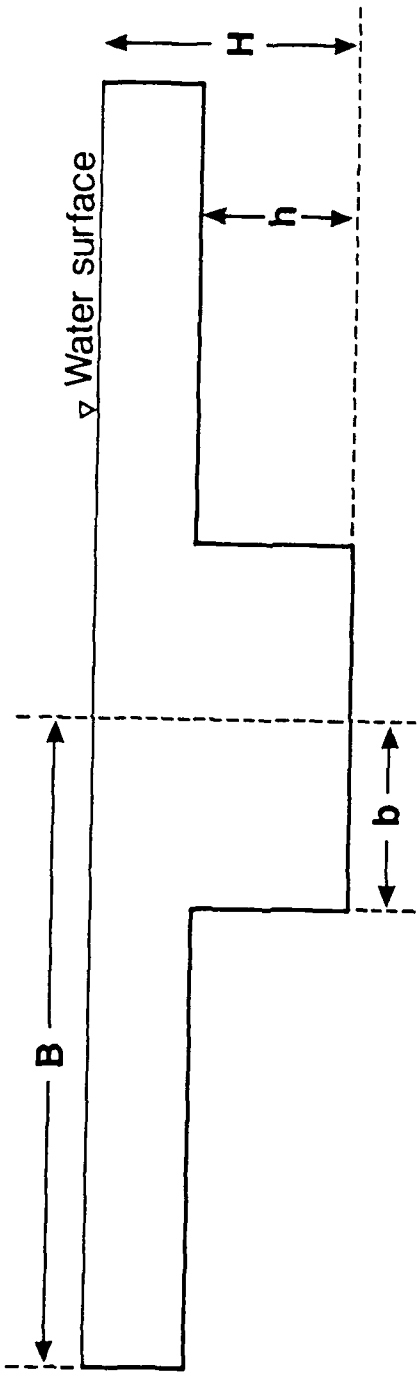

Figure 1.3
Two-Stage Channel Parameter Definition

where:

Sy - sediment yield (tons)
q_p - peak discharge ($ft^3 s^{-1}$)
R - runoff volume (acre ft)
E - soil erodibility factor
Cr - cropping management factor
Pr - erosion control practice factor
LS - slope length and gradient factor

1.1.2 Model control procedures

A number of model control procedures are also included in MILHY. These are illustrated in the upper row of figure 1.1. The user may select model control procedures in any order, or combination, to instruct the program to begin, to store a measured hydrograph or rating curve, to add two hydrographs together, to provide printed or plotted information, to analyse results and to terminate. A short description of each will serve to illustrate the flexibility which MILHY offers the user.

START - This provides the program with the start time for the simulation and instructs the program to begin.

STORE HYDROGRAPH - This allows the user to input a measured hydrograph for a particular subcatchment, directly into the computer memory. All hydrographs are limited to 300 points.

STORE RATING CURVE - This allows a measured rating curve for a particular cross section to be input directly into the computer memory. A maximum of twenty points to define the stage, end area, discharge relationship, are permitted.

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STORE TRAVEL TIME - This allows a previously computed travel time table to be input and stored in the program. A maximum of twenty points to define the depth, flow, travel time table, are permitted.

ADD TWO HYDROGRAPHS - MILHY initially calculates the hydrograph for the upstream subcatchment area and proceeds downstream by cumulating pairs of hydrographs. This model control procedure adds together the coordinates of two specified hydrographs.

PRINT HYDROGRAPH - According to the user's request, this procedure will either print out the whole of the hydrograph, or just the runoff volume and peak discharge rate values to a user specified peripheral.

PLOT HYDROGRAPH - This enables one or two hydrographs to be plotted out on the same axis. The plot is made on a line printer.

ERROR ANALYSIS - This model control procedure offers a number of indices which detail the goodness of fit of two hydrographs. The first two measures, the error standard deviation (ESD) and the percentage peak discharge error (PDE) were calculated in the original MILHY and are given by:

$$(ESD)^2 = \frac{\sum_{i=1}^{n} (qm_i - qc_i)^2}{n} \qquad 1.22$$

where:

- n - number of pairs of discharge measurements at equal time intervals
- qm_i - measured discharge ($ft^3 s^{-1}$)
- qc_i - calculated discharge ($ft^3 s^{-1}$)

and:

$$PDE = \frac{q_p m - q_p c}{q_p m} \times 100\% \qquad 1.23$$

where:

$q_p m$ - measured peak discharge ($ft^3 s^{-1}$)
$q_p c$ - calculated peak discharge ($ft^3 s^{-1}$)

A number of additional objective functions have been included:
Absolute sum of error (OF1):

$$OF1 = \sum_{i=1}^{n} (qm_i - qc_i) \qquad 1.24$$

Ordinary least squares (OF2):

$$OF2 = \sum_{i=1}^{n} (qm_i - qc_i)^2 \qquad 1.25$$

Log ordinary least squares (OF3):

$$OF3 = \sum_{i=1}^{n} (\log(qm_i) - \log(qc_i))^2 \qquad 1.26$$

Relative sum of errors (OF4):

$$OF4 = \sum_{i=1}^{n} \left(\frac{(qm_i - qc_i)}{qm_i} \right)^2 \qquad 1.27$$

Absolute error difference (OF5):

$$OF5 = \sum_{i=1}^{n} ((qm_i - qm_{i-1}) - qc_i - qc_{i-1}))^2 \qquad 1.28$$

Relative error difference (OF6):

$$OF6 = \sum_{i=1}^{n} \left(\frac{((qm_i - qm_{i-1}) - (qc_i - qc_{i-1})}{(qm_i - qm_{i-1})} \right)^2 \qquad 1.29$$

Absolute error divided by variance (OF7):

$$OF7 = \frac{\sum_{i=1}^{n} (qm_i - qc_i)^2}{\sum_{i=1}^{n} (qm_i - \bar{q}m)^2} \qquad 1.30$$

where:

$\bar{q}m$ - mean measured discharge

Relative error divided by variance (OF8):

$$OF8 = \frac{\sum_{i=1}^{n}((qm_i - qc_i)/qm_i)^2}{\sum_{i=1}^{n}((qm_i /\bar{q}m)-1)^2} \qquad 1.31$$

Absolute error difference divided by variance (OF9):

$$OF9 = \frac{\sum_{i=1}^{n} ((qm_i - qm_{i-1}) - (qc_i - qc_{i-1}))^2}{\sum_{i=1}^{n}((qm_i - qm_{i-1}) - \overline{(qm_i - qm_{i-1})})^2} \tag{1.32}$$

where:

$\overline{qm_i - qm_{i-1}}$ - mean of difference of measured hydrograph

Relative error difference divided by variance (OF10):

$$OF10 = \frac{\sum_{i=1}^{n}(((qm_i - qm_{i-1}) - (qc_i - qc_{i-1}))/(qm_i - qm_{i-1}))^2}{\sum_{i=1}^{n}(((qm_i - qm_{i-1})/(\bar{q}m_i - \bar{q}m_{i-1})) - 1)^2} \tag{1.33}$$

Pearsons correlation coefficient (OF11):

$$OF11 \quad \frac{1}{n} \sum_{i=1}^{n} \left(\frac{qm_i - \bar{q}m}{\sigma qm}\right)\left(\frac{qc_i - \bar{q}c}{\sigma qc}\right) \tag{1.34}$$

where:

$\bar{q}c$ - mean calculated discharge
σqm - standard deviation of measured discharge
σqc - standard deviation of calculated discharge

FINISH - When all hydrological and model control procedures which are required by the user have been completed, this procedure instructs the program to terminate.

1.2 The Physically Based Infiltration Model

This infiltration model is a physically based and dynamic model which provides the capability to continuously simulate one-dimensional, near surface soil water movement. During a storm, water supplied to the surface may either infiltrate or accumulate on the surface, and when a specified surface detention capacity is exceeded, runoff occurs. When precipitation ceases, water is redistributed by drainage and evaporation. This model is not spatially distributed, but all soil types in the subcatchment can be represented and variability of soil hydraulic properties may be further included into the model using a stochastic Monte Carlo method.

The infiltrtation model is based upon that developed by Anderson (1982) and Anderson and Howes (1984). It should be noted that all parameter units in this section are metric.

1.2.1 The mathematical model

The law governing the flow of water through a rigid, homogeneous isotropic, and isothermal porous media, is derived from two equations, Darcy's Law, and the principle of continuity.

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Darcy's Law states that the flow of water through a porous medium is proportional to the hydraulic gradient and the conductivity:

$$v = -K \nabla \emptyset \tag{1.35}$$

where:

v - marcroscopic vector velocity of water ($m\ s^{-1}$)

$\nabla \emptyset$ - gradient of total potential (metres) in 3-dimensional space

∇ - denotes $\frac{\delta}{\delta x} + \frac{\delta}{\delta y} + \frac{\delta}{\delta z}$

and:

$$\emptyset = \psi - z \tag{1.36}$$

where:

z - gravitational potential, depth from surface where downwards is positive (metres)

Darcy's Law holds for flow in unsaturated soils, but in slightly modified form, where K and U are functions of the soil moisture content (σ).

$$v = -K(\sigma) \nabla \emptyset \tag{1.37}$$

$$\sigma = \psi(\sigma) - z \tag{1.38}$$

The principle of continuity states that the difference between the inflow and outflow per unit time is equal to the rate of change in storage. The continuity equation is given by:

$$\frac{\delta \sigma}{\delta t} = -\nabla v \tag{1.39}$$

where:

t - time (seconds)

Combining equation 1.39 with equation 1.37 gives:

$$\frac{\delta\sigma}{\delta t} = \nabla(K(\sigma)\nabla\emptyset) \qquad 1.40$$

Rewriting equation 1.40 in one dimension, for vertical flow, where z is the vertical distance taken downward as positive gives:

$$\frac{\delta\sigma}{\delta t} = \frac{\delta}{\delta z}(K(\sigma)\frac{\delta\emptyset}{\delta z}) \qquad 1.41$$

Substituting equation 1.38 into equation 1.41 gives:

$$\frac{\delta\sigma}{\delta t} = \frac{\delta}{\delta z}(K(\sigma)\frac{\delta}{\delta z}(\psi(\sigma)-z)) \qquad 1.42$$

$$\frac{\delta\sigma}{\delta t} = \frac{\delta}{\delta z}(K(\sigma)\frac{\delta\psi}{\delta z}(\sigma)) - \frac{\delta K}{\delta z}(\sigma) \qquad 1.43$$

Equation 1.43 is equivalent to the Richards equation. To solve this equation for unsaturated conditions, the hydraulic conductivity function $K(\sigma)$ is required and is therefore derived numerically using the following relationship which has been established by Millington and Quirk (1959), and developed by Campbell (1974) and Jackson (1972). The relationship is described by:

$$K_i = K_s\,(\sigma_i/\sigma_s)^p \frac{\sum_{j=i}^{m}(2_j+1-2_i)\psi_j^{-2})}{\sum_{j=1}^{m}((2_j-1)\psi_j^{-2})} \qquad 1.44$$

where:

K_s - saturated hydraulic conductivity (ms^{-1})
θs - saturated soil moisture content ($m^3 m^{-3}$)
m - number of equal sized increments of moisture content
p - a constant, the pore interaction term

A value of unity for the pore interaction term has been assumed (Jackson, 1972).

Several points concerning the application of the Millington and Quirk method are relevant to this application:

1. To derive reliable results from the model, the soil moisture characteristic curve must be reliable, and should span a wide range of moisture values. The moisture curve should be a desorption curve; it has been observed that the pore size distribution is not well described by the wetting curve.

2. The method is not reliable for fine materials with a wide range of pore sizes, or for swelling soils. It is suitable for soils with stable structures.

3. The number of equal intervals (m, in equation 1.44) into which the soil water characteristic is divided was found by Kunze _et al_. (1968) to affect the prediction of the hydraulic conductivity function. Ten classes was found to be optimal.

The Richards equation is a nonlinear partial differential equation, to which exact solutions are available only for specific initial and boundary conditions. To solve equation 1.43, it is necessary to convert the mathematical model into a form which can be solved approximately by digital computer. After Hillel (1977), the equations are converted into explicit finite difference equations and solutions are defined at discrete points in space and time.

Inaccuracies due to approximation by finite difference can be made very small by the proper use of the method. In any case, errors are usually outweighed by inaccuracies in the specification of subsurface hydrological parameters. An explicit method, otherwise known as a forward difference method, uses coefficient and variable values at the beginning of a time step to predict values of dependent variables at the end of the time step.

The explicit solution is a simple algorithm, but it does not display the best convergence or stability characteristics. It is usually only conditionally stable and convergence depends upon small time and space increments. Consequently, a large number of computations are necessary. As a check on stability, throughout the simulation, a mass water balance calculation is repeated to identify whether numerical errors are large, and, if so, to identify where they become a serious problem. The mass water balance calculation is described by the following equation:

$$BAL = \sigma_{end} - \sigma_{init} - ci + ce + cd \qquad 1.45$$

where:

- Bal - numerical error ($m^3 m^{-3}$)
- σ_{end} - total water content of soil profile ($m^3 m^{-3}$) at end of simulation
- σ_{init} - initial total water content of entire profile ($m^3 m^{-3}$)
- ci - cumulative infiltration ($m\ s^{-1}$)
- ce - cumulative evaporation ($m\ s^{-1}$)
- cd - cumulative drainage ($m\ s^{-1}$)

If the value of (BAL) increases as the simulation proceeds, then either the time increment or the cell dimensions have to be reduced. In practice, the spatial and temporal increments must be kept small.

1.2.2 Basic structure of the infiltration model

In order to apply the mathematical infiltration model which has been described in the previous section, each major soil type in the catchment is represented as a soil column. The structure of the soil column is indicated in figure 1.4. It is divided into up to three layers; each is permitted to have different hydrological properties. All layers are further divided into cells, and flow between the midpoints of each cell is simulated under both saturated and unsaturated conditions. Detention capacity, expressed as an equivalent depth of water on the soil surface has to be exceeded by rainfall excess before runoff begins. When precipitation ceases, this store is depleted by infiltration and evaporation. Detention capacity is the only model parameter which is not a measurable characteristic. It is not physically based, but represents the net effect of vegetation, interception, litter interception, and surface detention. Its value also reflects the antecedent moisture conditions of vegetation and litter. The model can accommodate dynamic changes in model structure; it allows water tables and perched water tables to develop and fluctuate through time.

1.2.3 Data requirements

The data which are required by the infiltration model are discussed in Chapter 2. The soil hydrological characteristics are parameters which may not be commonly available for the ungauged catchment. It is suggested that the series of charts and regression equations which were developed by Brakensiek and Rawls (1983) for the ungauged application of the Green and Ampt infiltration model, may prove very useful in deriving the soil hydrological parameters required by the Richards equation. These charts and equations also allow the routine use of the infiltration model for the ungauged catchment (Anderson and Howes, 1984; Anderson et al., 1985; Anderson and Howes, 1986).

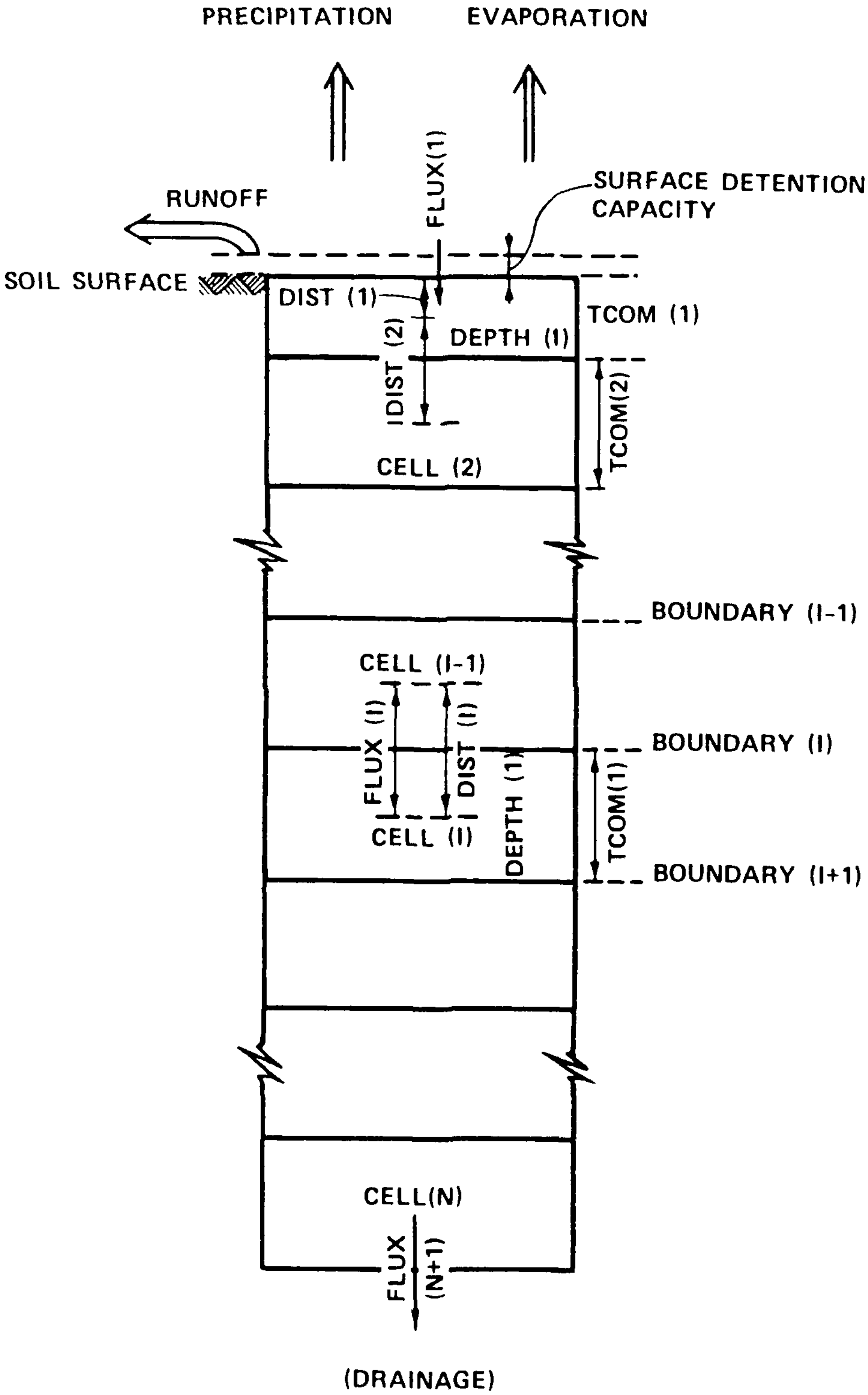


Figure 1.4
Schematic Structure of the Infiltration Algorithm

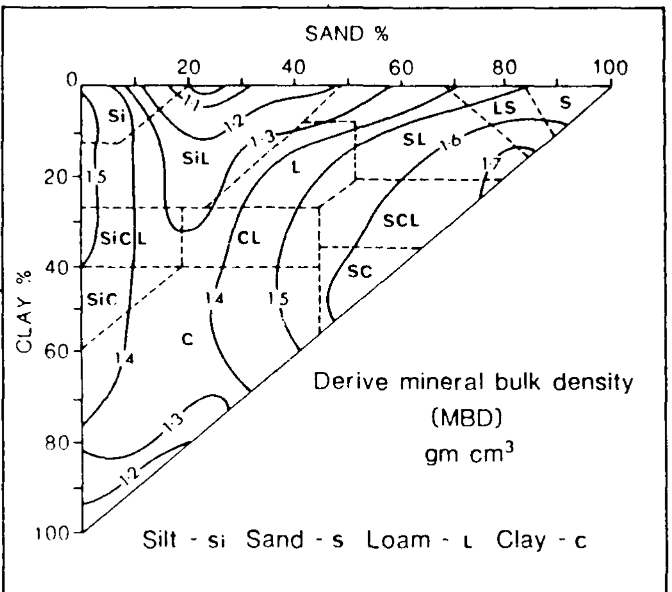
The charts and regression equations were developed from simulations based upon approximately 5,000 soil data sets in the United States, and represent average soil conditions prior to a particular agronomic practice. Figure 1.5 indicates that information concerning the percentage sand, clay and organic matter of a soil is all that is required to derive the moisture contents corresponding to a broad selection of suction values. Soil texture data are used to derive the mineral bulk density; these together with the percentage organic matter are used to determine soil bulk density, and all are then used in the regression equations to provide the moisture content at a number of specified suction values. The soil water potential at air entry is derived from a table published by Rawls et al. (1982) and which is reproduced in part in Table 1.2, and this provides an additional point for the soil moisture characteristic curve. Figure 1.6 illustrates the two charts from which values of saturated hydraulic conductivity and saturated moisture content can be derived relating to the soil's percentage of clay and sand.

1.2.4 Stochastic infiltration model

One of the major problems in applying the infiltration equation to a catchment is the spatial variation of the soil's physical, and therefore hydrological, properties. This variability leads to a lack of confidence in a deterministic model and thus a stochastic approach can additionally be adopted. Such a framework has been introduced into the infiltration model in an attempt to incorporate estimates of known spatial variability within a soil type, and to establish its consequences upon the predicted hydrograph. Thus a probability distributed model has been developed.

The variability of the five soil hydrological properties necessary to operate the model: detention capacity, the soil moisture characteristic curve, saturated soil moisture content, saturated hydraulic conductivity, and initial soil moisture

% sand
% clay
%org. matter



Evaluates soil bulk density (SBD)

$$SBD = \frac{100}{\frac{\%org.\ matter}{0.224} + \frac{100 - \%\ org.matter}{MBD}}$$

Table used to derive θ for each given ψ using the regression equation :

$$\theta = a_i + b_i(\%sand) + c_i(\%clay) + d_i(\%org.matter) + e_i(SBD)$$

Matric Potential - Bars	a	b	c	d	e	R^2
-0.20	0.4180	-0.0021	0.0035	0.0232	-0.0859	0.75
-0.33	0.3486	-0.0018	0.0039	0.0228	-0.0738	0.78
-0.60	0.2819	-0.0014	0.0042	0.0216	-0.0612	0.78
-1.0	0.2352	-0.0012	0.0043	0.0202	-0.0517	0.76
-2.0	0.1837	-0.0009	0.0044	0.0181	-0.0407	0.74
-4.0	0.1426	-0.0007	0.0045	0.0160	-0.0315	0.71
-7.0	0.1155	-0.0005	0.0045	0.0143	-0.0253	0.69
-10.0	0.1005	-0.0004	0.0044	0.0133	-0.0218	0.67
-15.0	0.0854	-0.0004	0.0044	0.0122	-0.0182	0.66

Suction - moisture curve

Figure 1.5
Derivation of the Suction-Moisture Curve from Soil Texture Information
(after Brakensiek and Rawls, 1983)

Table 1.2

<u>Bubbling pressure classified by soil texture</u>
(adapted from Rawls et al., 1982, Table 2)

Texture class	Sample size	Bubbling pressure (metres)
Sand	762	0.15
Loamy sand	338	0.21
Sandy loam	666	0.30
Loam	393	0.40
Silt loam	1206	0.51
Sandy clay loam	498	0.59
Clay loam	366	0.56
Silt clay loam	689	0.70
Sandy clay	45	0.79
Silty clay	127	0.77
Clay	291	0.86

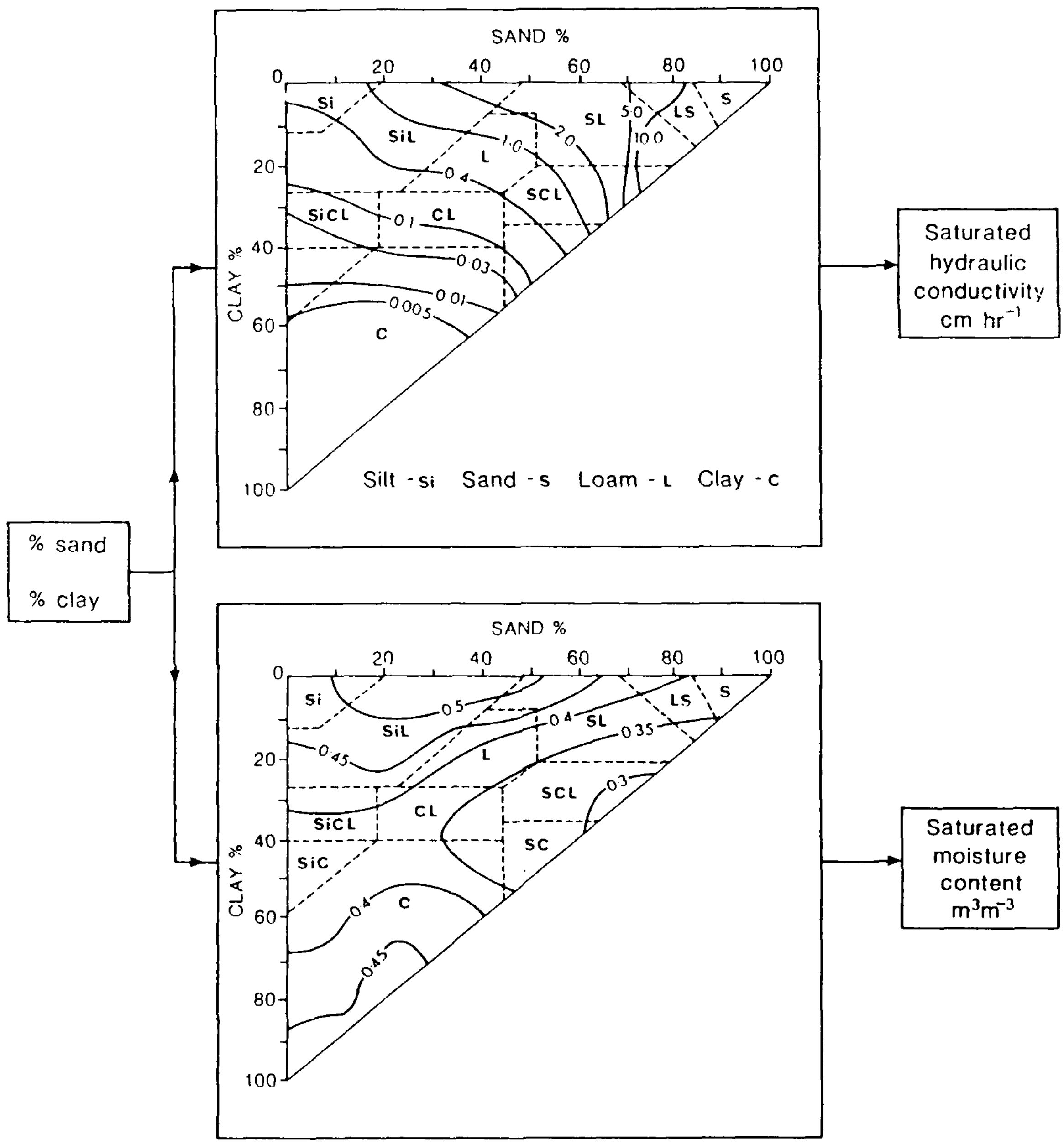


Figure 1.6

Derivation of Saturated Hydraulic Conductivity and Saturated Moisture Content from Soil Texture Information

conditions, is described by conventional statistics. Each is considered to be an independent random variable and may be described by a suitable probability density function, derived from the literature. There is evidence that log-normally distributed hydraulic conductivity and other soil hydrological properties have been shown to display normal distributions. For this model, detention capacity was assumed to be normally distributed. It is acknowledged that catchment variability is not without spatial structure, but insufficient geostatistical information describing the characteristics of this structure is currently available for incorporation into the model. The assumption of independence will, however, provide predictions for the 'worst case' situation; incorporation of spatial autocorrelation would decrease model output variance.

A procedure has been built into the infiltration model program which generates random values for the five soil hydrological parameters. The random number generator which has been used is a NAG (Numerical Algorithm Group) routine, reference number G05DDF, which returns a 'pseudo-random' number from a normal probability distribution. There are three requirements to generate the random numbers in the infiltration model for each of the five input parameters:

1. The specification of a probability distribution.
   This is an expression of the relative likelihood of different parameter values.

2. The mean and standard deviation.
   The mean reflects the average value of the parameter and the standard deviation reflects the magnitude of error of the estimate.

3. The ranges of the physically allowable parameter values.
   These reflect some knowledge of the possible field ranges.

The NAG routine, G05DDF, is therefore called which returns the random value from a normal distribution provided that the mean and standard deviation are specified. The normal distribution in this algorithm is given by:

$$p(x) = \frac{1}{\sqrt{(2\pi\sigma)}} \exp\left(\frac{-(x-\bar{x})^2}{2\sigma^2}\right) \qquad 1.46$$

where:

$p(x)$ - probability of (x)

σ - standard deviation

$\bar{x}$ - mean

As neither the normal nor log-normal distributions are bounded at the tail, there is a small probability of randomly generated values assuming negative values. Checks are therefore performed on the generated values, to ensure physical consistency. Total independence of the five parameters cannot be assumed. Many checks which are enforced involve adjusting parameter values according to the values which have been generated for the other parameters.

The procedure for the stochastic variation of each of the five parameters will be discussed in turn.

Detention capacity

The random number generated from the normal distribution is constrained only by the condition that it cannot assume a value of less than zero. If the generated value does fall below this limit, it is set to zero.

Chapter 1

Saturated soil moisture content

As the infiltration model is capable of simulating up to three hydraulically different layers, three different means and standard deviations may be entered into the program. The value is generated randomly for each layer from the normal distribution and then checked against the largest moisture value in the soil moisture characteristic curve. If the saturated soil moisture content is smaller than this value, then it is reset equal to the largest moisture values in the curve.

Soil moisture characteristic curve

As for the saturated soil moisture content, up to three curves may be input to the model, one for each layer in the soil column. For each curve and for each tension the moisture content is allowed to vary according to the normal distribution with a given mean and standard deviation. The procedure begins with the smallest moisture content. If this randomly generated value is less than zero, then its value is set to 0.001. Random numbers are then generated for the other moisture contents. If any randomly generated value is less than or equal to the previous values, then it is set equal to the value plus a small increment. Thus reverse gradients are not allowed to develop in the curve. The largest moisture value is finally compared to the saturated soil moisture content as has been described.

An alternative method would be to randomly generate one moisture value, to then find the difference between the randomly generated moisture value and the mean, and finally to increment all moisture values by this difference. However, this procedure would not allow variation in the standard deviation with soil moisture tension and there is evidence in the literature that this may be the case.

Saturated hydraulic conductivity

Again, a mean and standard deviation can be entered for each layer. As this parameter is considered to be log-normally distributed, for each layer, the logarithm of the mean is taken. This is used to generate the random number from the normal distribution and the antilogarithm of the generated number is then taken. There are no checks on the generated value.

Initial moisture content

The randomly generated value for initial moisture content is generated for each cell in the soil column. Each is compared to the saturated soil moisture content for the relevant layer. If it exceeds this value, then it is set equal to the limit. The initial moisture content is also checked against the moisture values in the soil moisture characteristic curve for the layer. To calculate unsaturated conductivity values, the initial moisture content of each cell must lie within this range.

1.2.5 Implementation

The infiltration model, which includes the option as to whether or not a stochastic application is required, was developed on a mainframe, the Honeywell 6800 under Multics. All further developmental work and validation was undertaken on the SUN 3/60 workstation under Unix. Figure 1.7 indicates the alternative procedures available within the MILHY model suite. The stochastic model does produce more than one hydrograph and these are all stored. All hydrographs produced may then be plotted out, or, alternatively, statistics which describe the characteristics and the variability of the predicted hydrographs may be calculated.

In application of the infiltration algorithm for runoff prediction to a catchment or subcatchment, the area does not have

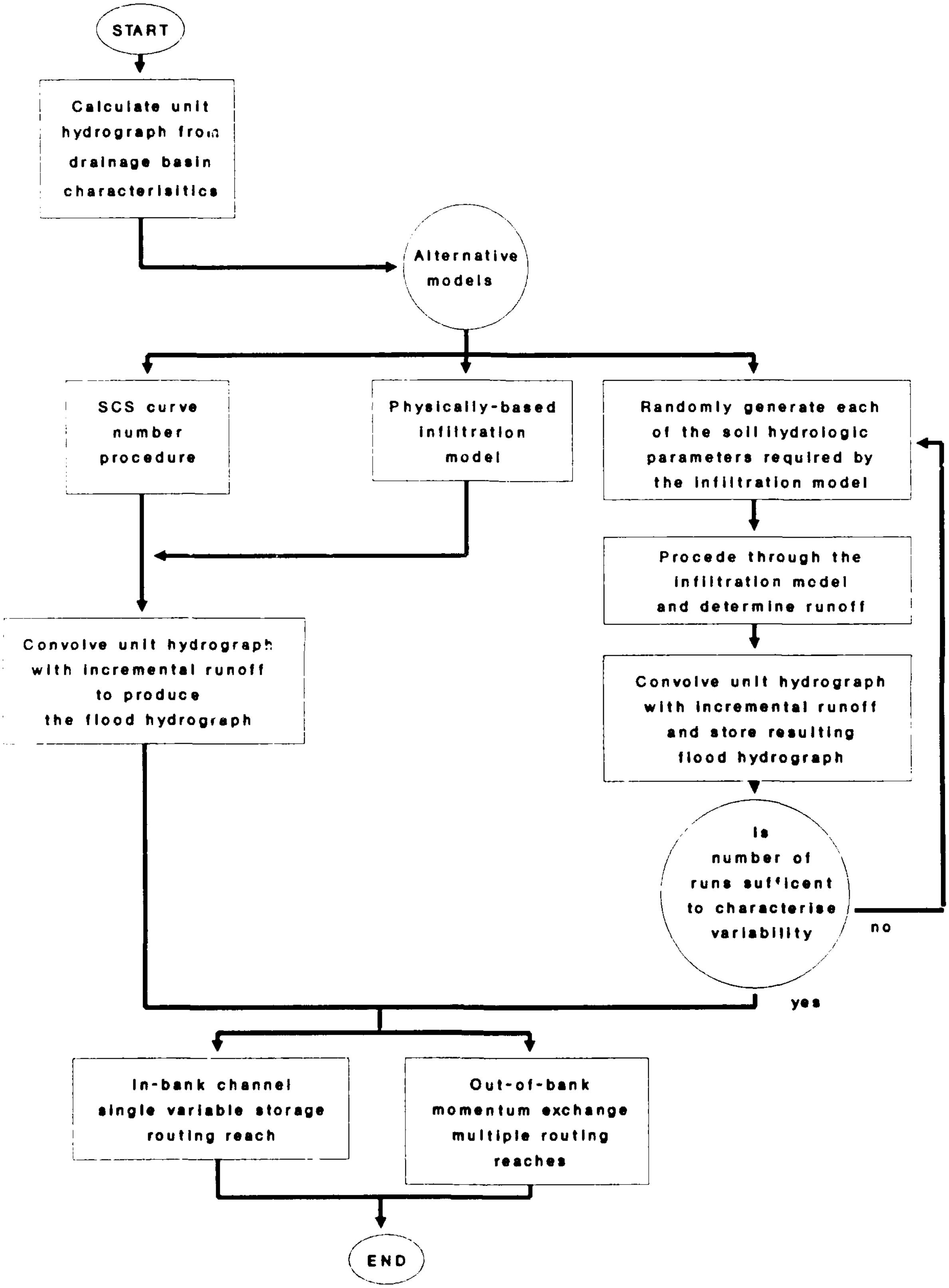


Figure 1.7
Alternative Procedures for Derivation of the
Flood Hydrograph Utilising MILHY3

to be assumed to be homogeneous. Soil conditions can be represented by more than one soil column. Soil hydrological information for each of the major soil series or groups in the area is used to set up a soil column (figure 1.4) for each soil type. In order to combine the relative contributions of runoff provided by each of the soil types, the complete storm is applied to each of the soil columns, and the incremental runoff produced by each is weighted according to the percentage area of the catchment occupied by that particular soil type. These relative contributions are then summed to produce the total runoff volume derived from the subcatchment. It should be stressed, however, that the relative locations of each soil type are not explicitly taken into account.

Any decision concerning the number of soil columns which will be used to describe the subcatchment area will have to trade the advantages of a more complete representation of the conditions with the disadvantages of an increase in data acquisition and computer requirements and will depend upon the user's requirements. The user is recommended to read Chapter 7 in Volume 1 of this report, where guidelines are given for the selection of process modules in the MILHY3 suite.

Chapter 2
MILHY3 - Data Sets

2.1 Introduction

All input data for MILHY3 is contained in 'datal' and 'data2' data sets. The basic nature of these two data sets remains unchanged from MILHY2, where program commands and hydrological data are provided in 'datal' and soils data for the infiltration algorithm are provided in 'data2'. In MILHY3 both files are assumed to exist irrespective of the use of the infiltration algorithm. A summary of the nature of the data preparation and checking procedures is shown in Figure 2.1.

This chapter is split into three parts: a description of the two data sets, and a worked example with results.

2.2 Data Set 'datal'

The 'datal' data set contains all the hydrological procedures and consequent data requirements and the model control procedures for a simulation. There are fifteen legal commands accepted by MILHY3, which must be entered in columns 1-20 of the data set. No typing or spelling errors are accepted and on most machines the commands must be in upper case. The legal commands are:-

Model control procedures:

START
STORE HYD
STORE RATING CURVE
STORE TRAVEL TIME
ADD HYD
PRINT HYD
PLOT HYD
ERROR ANALYSIS
FINISH

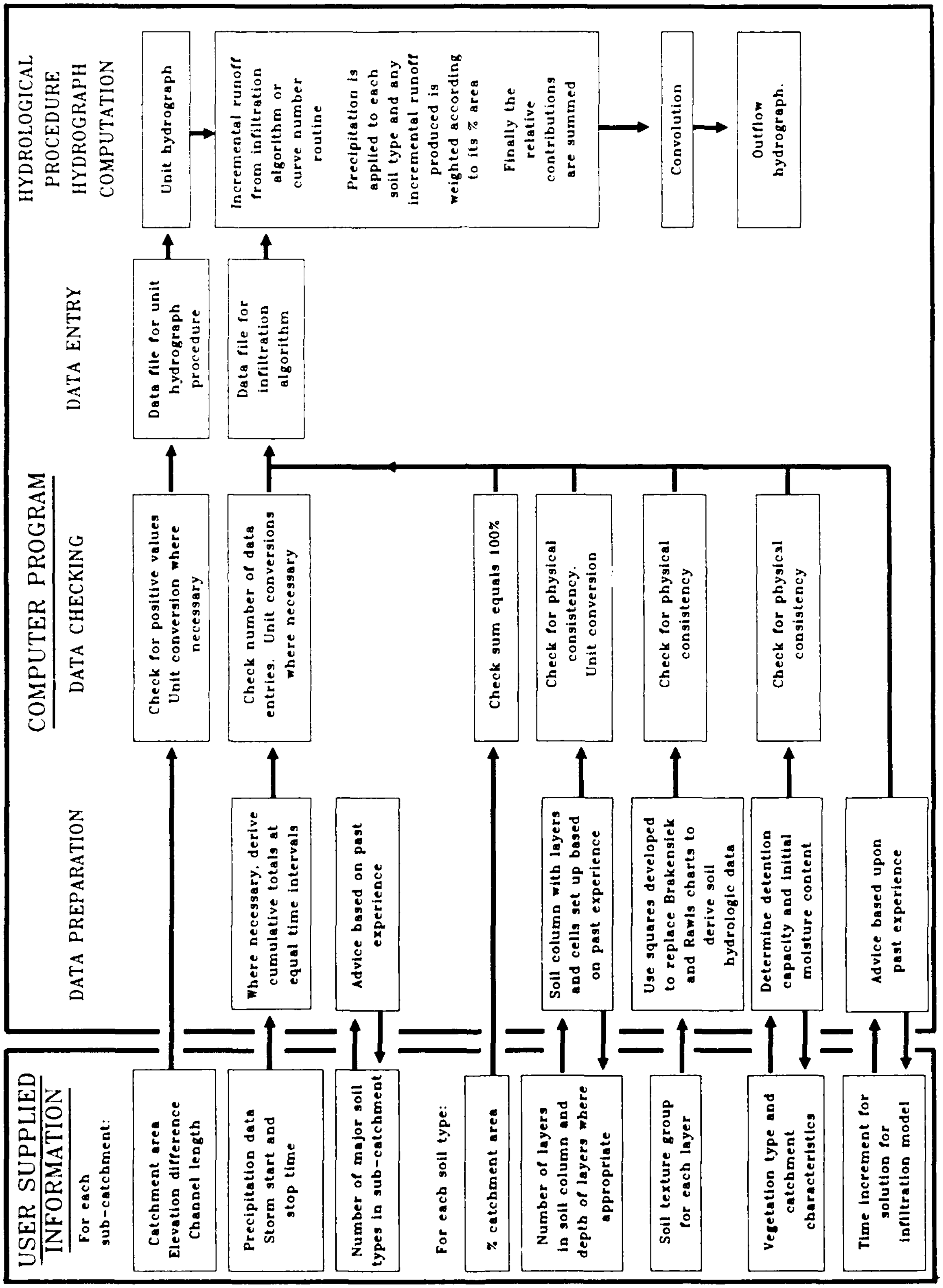


Figure 2.1
Data Preparation and Checking Procedures for the MILHY3 Scheme

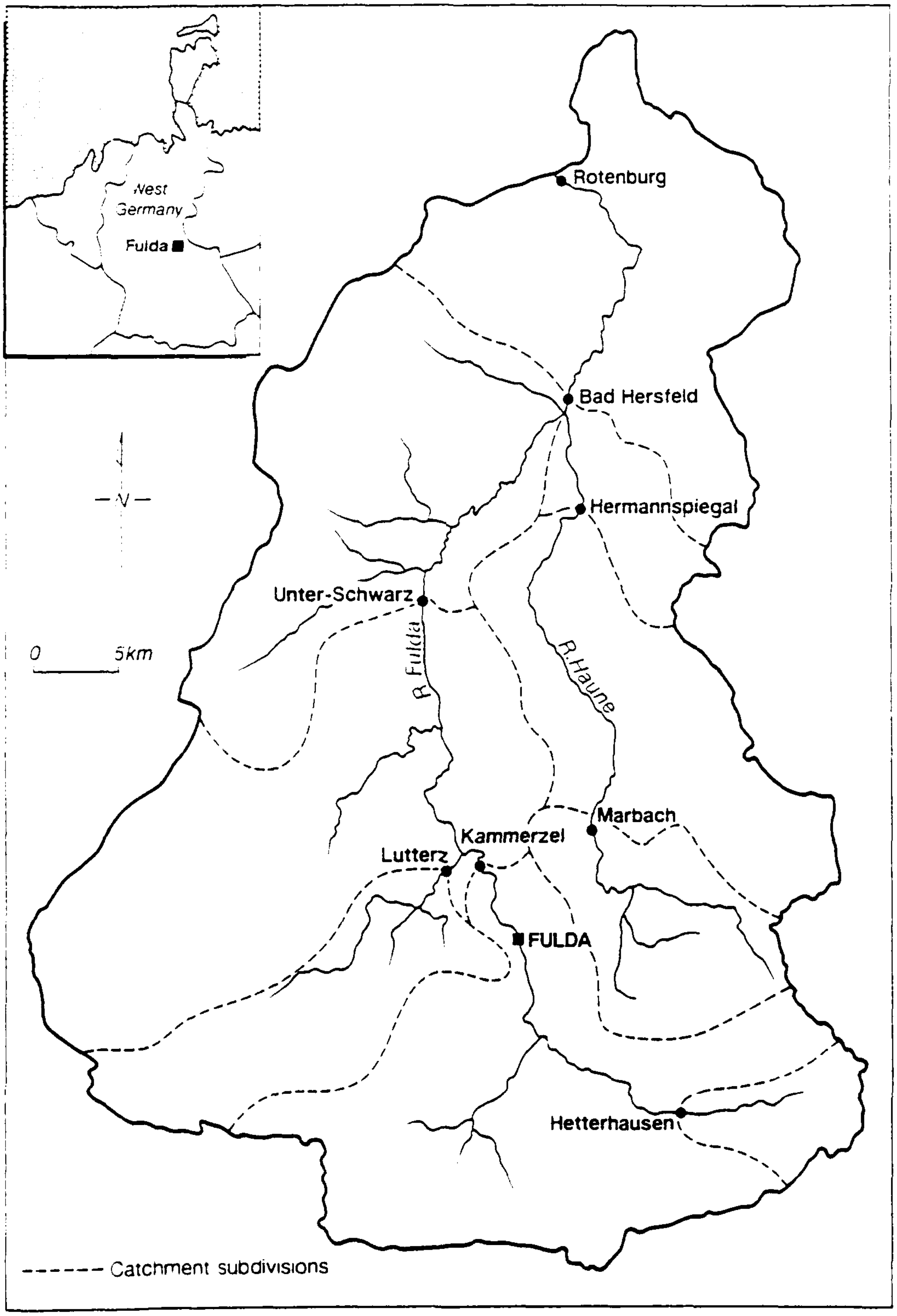


Figure 2.2
Location of example simulation, River Fulda, West Germany

Chapter 2

Hydrological procedures:

COMPUTE HYD
COMPUTE RATING CURVE
COMPUTE TRACEL TIME
ROUTE
ROUTE RESERVOIR
SEDIMENT YIELD

An '*' in column 1 means that the line is a comment.
An '*' in column 80 means skip to a new page before writing to file.

Each of these commands requires some further identification data or field/topographic data. All data must be entered in columns 21-80, and it must appear in the order specified. The data may be surrounded by as much text as required by the user for identification, but care should be taken that such identifiers do not include any numbers. Data is separated by at least one blank space between each data item.

Six hydrographs can be stored in a MILHY program at a time. The hydrographs are identified by storage location numbers 1 through 6. Therefore, the same storage location number must be used for many hydrographs in a MILHY program. This is especially true when routing is done through large watersheds. However, no more than six hydrographs are ever needed at one time because MILHY programs begin at the head of a watershed and work downstream through one reach at a time. When a storage location number is used to store or compute another hydrograph, the first hydrograph is lost. The user should be sure that the hydrograph will not be referred to again before using the storage location number for another command.

To store, compute, or route a hydrograph, the user must specify the time increment. There are no rigid rules about selecting the time increment, but generally it should not be

greater than one-fifth of the time to the peak of the hydrograph. This rule usually provides enough points to adequately define the hydrograph. All hydrographs are limited to 300 points.

For the commands STORE HYD, COMPUTE HYD, ROUTE and ROUTE RESERVOIR, the user must specify the number of the outflow hydrograph. The hydrograph identification numbers are used to designate specific routing reaches, incremental areas, reservoirs, and partial hydrographs. The partial hydrograph number is given to all hydrographs other than outflow hydrographs from reaches, incremental areas, or reservoirs. The recommended identification numbers for each group are:

Reaches..1-100
Partial hydrographs........................101-300
Incremental areas..........................301-500
Reservoirs.................................501+

Each of the fifteen legal commands and their data requirements are now described in detail and summarised in Table 2.1. An example data set and results file is documented in section 2.4.

START

The first command for any watershed is START. The three data items associated with this command are the time start and the control data specifying the units of data input and output. A code of zero indicates imperial units are to be used, a value of 1 indicates metric units.

Chapter 2

STORE HYD

The STORE HYD command is used to store the coordinates of a hydrograph in the computer. It can be used for storing measured hydrographs or hydrographs computed by methods other than the ones used in MILHY. The input data required for STORE HYD are storage location number, hydrograph identification number, time increment, watershed area, and flow rates of the hydrograph at the specified time increment.

COMPUTE HYD

The COMPUTE HYD command is used to compute hydrographs from the incremental areas of the watershed. The first five items of data are storage location number, hydrograph identification number, time increment, watershed area, and SCS runoff curve number. A zero value is entered for the SCS CN if the infiltration algorithm is to be invoked. Normally, data items 6 and 7 are watershed height and main stream length. The height and length are used to compute the recession constant K and the time to peak t_p. However, if K and t_p are known or estimated by some other method, they can be entered directly into the program. This is accomplished by placing a minus sign before the values of K and t_p and entering them as data items 6 and 7, respectively. The remaining data items are values of the cumulative rainfall at the specified time increment.

Since most watersheds have a limited number of rain gauges, the same mass rainfall data may be used to develop several hydrographs.

PRINT HYD

The PRINT HYD command is used to print coordinates of a hydrograph, volume of runoff, and peak flow rate. The required input data are the storage location number, peak-volume code, rating

curve storage location, number and format identifier. The peak-volume indicator is used to identify the form of hydrograph output. A zero value would produce just peak discharge and hydrograph volume data. A value of 1 would produce the whole discharge hydrograph, whilst a value of 2 would generate a stage hydrograph utilising the rating curve identified as the third data input. The format identifier if set to 1 will produce a hydrograph as a single column of data, without the time interval data. This enables easier transfer of data to graphics or statistical packages. A format value of zero will retain the normal five column MILHY output.

PLOT HYD

The PLOT HYD command is used to plot hydrographs in a MILHY program. It will plot one hydrograph on a set of axes, or if a comparison is desired, it will plot two hydrographs on the same set of axes. The required input data are the storage location numbers of the hydrographs to be plotted.

ADD HYD

The ADD HYD command adds the coordinates of any two hydrographs. The hydrographs are added at a time increment equal to that of the hydrograph with the shorter time increment. The only data required are the storage location number and hydrograph idenfication number of the added hydrograph and the storage location numbers of the two hydrogrgaphs to be added.

STORE RATING CURVE

The STORE RATING CURVE command is used to store rating curves that have been measured or computed previously. STORE RATING CURVE will save considerable computer time if measured or computed rating curves are available. The input data are the storage location number, valley section number and individual rating curve points

described by elevation, end-area, and flow rate. The number of points used to describe a rating curve is limited to 20.

COMPUTE RATING CURVE

The COMPUTE RATING CURVE command is used to compute the stage-area-flow relationship for a valley section. The input data and storage location number, momentum exchange indicator, multiple routing indicator, valley section number, number of segments in the valley section, minimum elevation, maximum elevation, channel and flood-plain slopes, Manning's n value, and segment boundary point for each segment, and horizontal and vertical position of points describing the valley section.

The storage location numbers of the valley sections in a particular reach must begin with 1, and increase by one for each valley section in the reach. However, the numbers are assigned without regard to upstream or downstream order. The valley section identification number can be any number from 0.1 to 999.9. These rules concerning storage location and valley section identification numbers also apply to the STORE RATING CURVE command.

Normally, valley sections are divided into three segments (two flood-plain segments and channel segment) for computing the rating curve. However, some valley sections may have more than one channel, or may have an extreme variation in n values acrcoss the flood plain, thus requiring more than three segments. A maximum of six segments is permitted. Manning's values for each segment are input with segment boundary point (distance from the beginning of the valley section to the end of the segment). Flood-plain n values are positive and channel n values are negative.

Twenty points are used to define a rating curve. The location of the points is determined by dividing the difference between the maximum and minimum elevations into 19 equal increments.

The momentum exchange indicator determines which of four techniques is used to develop the rating curve under out-of-bank conditions. A zero value will ensure the MILHY or MILHY2 version is utilised. Otherwise a value of 1,2,3 or 4 must be selected, where 1 introduces the least momentum exchange and 4 the most. Technique 4 will therefore reduce the computed discharge capacity at a particular stage elevation in comparison to technique 1.

The multiple routing indicator (set to 1 to invoke, 0 to not invoke) will cause separate rating curves to be developed for each flow segment. The flow segments can then be routed separately downstream using a COMPUTE TRAVEL TIME and ROUTE command for each flow segment.

COMPUTE TRAVEL TIME

The COMPUTE TRAVEL TIME command is used to compute the normal flow travel time relationship used in ROUTE. The input data are storage location number, reach identification number, number of valley sections in the reach, reach length, slope, multiple routing indicator, and rating curve segment identifiers. The reach identification number can be any number from 0.1 to 999.9. The maximum number of valley sections per reach is six. The slope can be either the channel or flood-plain slope or a weighted average of the two. If flow is confined to the channel, the channel slope is of course applicable. If most of the flow is in the flood plain, usually the flood-plain slope is used. However, a weighted slope based on the relative rates of flow in the channel and the flood plain may be used.

The COMPUTE TRAVEL TIME command considers each rating curve in the reach in computing the travel time flow relationship. COMPUTE TRAVEL TIME automatically selects the flow rates that are used in computing individual travel times. The flow rates of the rating curve with the lowest maximum flow rate are chosen. If the flow

rates of any other rating curve in the reach were chosen, the rating curve with the lowest maximum flow rate would have to be extrapolated. The travel time table is limited to 19 points, because of the 20-point limit for rating curves.

If multiple routing is invoked, only two rating curve flow segments are investigated. These segment rating curves are identified using a two digit number. The first digit is the storage location number used in the COMPUTE RATING CURVE command when the segment rating curve was developed. The second digit is the segment number.

STORE TRAVEL TIME

The input data for STORE TRAVEL TIME are storage location number, reach identification number, reach length, slope, and individual points of the relationship defined by depth, flow, and travel time.

ROUTE

The ROUTE command is used to route floods through streams and valleys. The input data are storage location number and hydrograph identification number of the outflow hydrograph, storage location number of the inflow hydrograph, time increment, and multiple routing indicator. The storage location number of the outflow hydrograph must be the same as the storage location number used in COMPUTE TRAVEL TIME for the reach. To prevent unnecessary program stoppage, ROUTE extrapolates the travel-time table when it is exceeded and writes the message, "TRAVEL TIME TABLE EXCEEDED".

If multiple routing is invoked, a separate ROUTE and COMPUTE TRAVEL TIME command is needed for each flow segment.

Chapter 2

ROUTE RESERVOIR

The ROUTE RESERVOIR command is used to route floods through reservoirs. The input data are storage location number and hydrograph identification number of the outflow hydrograph, storage location number of the inflow hydrograph, and individual points of the reservoir's outflow-storage relationship. The outflow-storage relationship must be expressed in 20 points or less. If the outflow-storage relationship is exceeded, ROUTE RESERVOIR will extrapolate the relationship and write the message, "STORAGE-DISCHARGE TABLE EXCEEDED".

ERROR ANALYSIS

The ERROR ANALYSIS command is used to determine the error standard deviation and the percentage error in peak flow between any two hydrographs in a MILHY program. These functions make ERROR ANALYSIS useful in research. The input data are the storage location numbers of the two hydrographs to be analyzed.

SEDIMENT YIELD

The SEDIMENT YIELD command is used to compute the sediment yield at any point in a watershed. Input data required are storage location number of the hydrograph from the area, a soils factor, a crop factor, a slope length and gradient factor, and a conservation practice factor.

FINISH

The FINISH command is used to end MILHY programs. There are no data associated with FINISH.

Table 2.1

Data for legal commands of MILHY3
in 'datal' data set

HYDROLOGICAL PROCEDURE	Variable used in subroutine
COMPUTE HYD	
Storage location number for hydrograph	ID
Hydrograph identification number	NHD
Time increment for rainfall data (hours)	DT(ID)
Watershed area (sqmi/km^2)	DA(ID)
Curve number (enter zero if not invoked)	CN
Watershed height, maximum difference (ft/m)	HT
Main stream length (mi/km)	XL
Rainfall, cumulative totals (inches/mm)	RAIN(300)
COMPUTE RATING CURVE	
Storage location number for rating curve	ID
Turbulent exchange of momentum between segments (not invoked enter 0) (invoked, enter 1-4 depending on method)	IT
Multiple routing reaches (not invoked enter 0) (invoked enter 1)	MR
Valley section location number	VS
Number of segments in channel (max. of 6)	NSEG
Minimum elevation (ft/m)	ELO
Maximum elevation (ft/m)	EMAX
Channel slope	SLOPE1
Floodplain slope	SLOPE2
Manning 'n' for each segment (negative value for channel segments)	SEGN(NSEG)
Segment boundary points (horizontal distance) (ft/m)	DIST(NSEG)
Cross-section co-ordinates (distance then elevation) (ft/m)	DATA(12,311)
COMPUTE TRAVEL TIME	
Storage location of travel time table	ID
Reach identification number	REACH
Number of valley sections in reach	NOVS
Reach length (ft/m)	XL
Slope (average for flow segments)	SLOPE
Multiple routing reaches (not invoked do not enter) (invoked enter one)	MR

Table 2.1 (cont.)

Inflow rating curve identification)	INRC
Outflow rating curve identification (first digit is storage location of the rating curve, the second digit is the segment number)	LRC

N.B. If multiple routing reaches not invoked do not enter values for INRC and LRC

ROUTE

Storage location number of outflow hydrograph	ID
Hydrograph identification number of outflow hydrograph	NHD
Storage location number of inflow hydrograph	IDH
Time increment (hrs)	DT(ID)
Multiple routing reaches (not invoked, do not enter) (invoked, enter one)	MR

ROUTE RESERVOIR

Storage location number of outflow hydrograph	ID
Hydrograph identification number of outflow hydrograph	NHD
Storage location number of inflow hydrograph	IDH
Reservoir outflow storage relation (max 20 points)	DT(ID)

SEDIMENT YIELD

Storage location of number of hydrograph	ID
Soil, crop, conservation and gradient factors	SOIL, CROP, CP, SL

Table 2.1 (cont.)

MODEL CONTROL PROCEDURES

START

Start time (hours)	TIME
Data input	KCODE
imperial enter zero	
metric enter one	
Data output	ICODE
imperial enter zero	
metric enter one	

STORE HYD

Storage location number for hydrograph	ID
Hydrograph identification number	NHD
Time increment for discharge data (hrs)	DT(ID)
Watershed area (sq.mi/km^2)	DA(ID)
Baseflow (added to discharge) (cfs/$m^3 s^{-1}$)	BSF
Discharge (300 points max.) (cfs/$m^3 s^{-1}$)	OCFS(300,ID)

RECALL HYD

Storage location number for hydrograph	ID
Hydrograph identification number	NHD
Time increment for discharge data (hours)	DT(ID)
Watershed area (sq.mi/km^2)	DA(ID)
Peak discharge (cfs/$m^3 s^{-1}$)	PEAK(ID)
Runoff volume (cf/m^3)	ROIN(ID)
Number of points in hydrograph)	IEND(ID)
Discharge (cfs/$m^3 s^{-1}$)	OCFS(300,ID)

STORAGE RATING CURVE

Storage location number for rating curve	ID
Valley section number	VS
Rating curve points	
elevation (ft/m)	DEEP(20,ID)
end area (ft^2/m^2)	A(20,ID)
flow rate (cfs/$m^3 s^{-1}$)	Q(20,ID)

STORAGE TRAVEL TIME

Storage location number for travel time table	ID
Reach identification number	NHD

Table 2.1 (cont.)

Length of reach (ft/m)	XL
Slope either channel or flood plain or weighted average of the two	SLOPE
Depth (ft/m)	DP(ID)
Discharge (cfs/m^3s^{-1})	SCFS(20)
Storage coefficient	C(20)

ADD HYD

Storage location number for resultant hydrograph	ID
Hydrograph identification number of resultant	NHD
Storage location of two hydrographs to be added	ID1, ID2

PRINT HYD

Storage location number of hydrographs	ID
SpeciSTORAGEfication of type of ourput	NPK

0 *peak and volume only* (cfs/m^3s^{-1})
1 discharge hydrograph (cfs/m^3s^{-1})
2 stage hydrograph (ft/m)

Rating curve identification for conversion of hydrograph	IDR

PLOT HYD

Storage location number of the 1 or 2 hydrographs to be plotted	ID1, ID2

PUNCH HYD

Storage location number of hydrograph	ID

ERROR ANALYSIS

Storage location numbers of 2 hydrographs to be compared	ID1, ID2

FINISH

No information required

Chapter 2

2.3 Data Set 'data2'

This data set contains all the information required by the infiltration algorithm. In contrast to the 'data1' data set, 'data2' contains variables separated by a space, no text or comment lines may appear. Data may be entered in columns 1 to 80 and must appear in the correct order. Table 2.2 summarizes the variables required by 'data2' and the order in which they must appear. Line numbers are not required in the data file but are provided here for convenience. A set of data for each soil column to be simulated must be entered. The runoff generated from each column is then weighted depending on the percentage contribution of that column in a particular subcatchment. Computations for each subcatchment are carried out individually in line with upstream to downstream progression utilised by all the MILHY3 models.

Each variable is now defined in turn. An example 'data2' dataset and corresponding results file is documented in section 2.4.

Line 1

TIME	simulation start time	hours and minutes where hours are 24 hour clock and minutes are decimals of hours, e.g. 20.45 becomes 20.75
ALR	storm start time	
AMR	storm stop time	
SIMDUR	simulation duration	

Chapter 2

Line 2

IOUT printout control, 1 = full printout, 0 = restricted printout

Line 3

AF simulation iteration periods (secs), for accuracy needs to be small, as a guide try 60 secs iterations

WT write out interval (hours)

Line 4

NSCOL number of soil columns in particular subcatchment; if more than 1, repeat lines 5-22 for each additional column

Line 5

IPAREA percentage area of subcatchment, represented by soil column 1

Line 6 data from lines 6-22 is for soil column 1

NL number of cells

NL1 number of cells in layer (horizon) 1

NL2 number of cells in layer (horizon) 2

Line 7

TCOM (I), I = 1, NL

thickness of cells (m), entered for NL cells

Line 8

EMAX maximum midday evaporativity (ms^{-1})

ADETCAP mean surface detention capacity (m), double precision

SDETCAP standard deviation detention capacity, double precision - set to zero if stochastic version not used

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Line 9

ASRI mean saturated soil water content (m^3m^{-3}) for layer (horizon) 1, double precision

SSRI standard deviation of saturated soil water content for layer (horizon) 1, double precision, set to zero if stochastic model not used

ASR2 as above for layer 2

SSR2 as above for layer 2

ASR3 as above for layer 3

SSR3 as above for layer 3

Line 10

ASATCON1 mean saturated conductivity (ms^{-1}) for layer 1, double precision

SSATCON1 standard deviation saturated conductivity for layer 1, double precision, set to zero if stochastic model not used

ASATCON2 as above for layer 2

SSATCON2 as above for layer 2

ASATCON3 as above for layer 3

SSATCON3 as above for layer 3

Line 11

ATHETA (I), I = 1, NL

mean initial soil water content (m^3m^{-3}) for each of NL cells

Line 12

STHETA standard deviation soil water content for soil column, double precision, set to zero if stochastic model not used

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Line 13

NQ number of observations in suction moisture curve

Line 14 line 14-16 - layer 1
17-18 - layer 2
20-22 - layer 3

AX(I),I = 1, NQ

mean soil moisture values ($m^3 m^{-3}$) for layer 1, NQ observations, at Y suction values, the last value needs to be the saturated soil water content, i.e. ASR1, double precision

Line 15

y1(I),I = 1, NQ

suction values (m) for layer 1, NQ observations corresponding to AX moisture values. As the last AX observation is at saturation, the last suction observation must be close to zero

Line 16

SCURV1 standard deviation of soil water content in suction moisture curve for layer 1, double precision. Set to zero if stochastic model not used

Line 17 AX2(I),I = 1, NQ

Line 18 y2(I),I - 1, NQ

Line 19 SCURV2

Line 20 AX3(I),I = 1, NQ

Line 21 y3(I),I = 1, NQ

Line 22 SCURV3

For each column, lines 5-22 are repeated, for each subcatchment lines 1-22 (+(5-22) x soil columns) are added. Each soil column or subcatchment follows directly from previous data entry; no extra spaces or lines are required.

If observed data for the soil hydrologic characteristics is not available, (e.g. AX, ASR), these may be generated from the Brakensiek and Rawl charts described in section 1.2.3.

2.4 Example Data Sets and Results File

The example shown here aims to generate a runoff hydrograph from the River Fulda shown in Figure 2.2. Observed inflows will be used, to input flow at Unter-Schwarz on the River Fulda, and to simulate flows from the tributary, the River Haune. MILHY3 will be used to simulate out-of-bank flows from these stations to the outflow at Rotenburg.

Table 2.2

Data requirements for 'data2'

Line no.	
1	TIME ALR AMR SIMDUR
2	IOUT
3	AF WT
4	NSCOL
5	IPAREA
6	NL NL1 NL2
7	TCOM(I),I=1,NL
8	EMAX ADETCAP SDETCAP
9	ASR1 SSR1 ASR2 SSR2 ASR3 SSR3
10	ASATCON SSATCON ASATCON1 SSATCON2 ASATCON3 SSATCON3
11	ATHETA(I),I=1,NL
12	STHETA
13	NQ
14	AX(I)mI=1,NQ
15	Y(I),I=1,NQ
16	SCURV1
17	AX2(I),I=1,NQ
18	Y2(I),I=1,NQ
19	SCURV2
20	AX3(I),I=1,NQ
21	Y3(I),I=1,NQ
22	SCURV3

If there is more than 1 soil column, then repeat from line 5, until all information is provided. No blank line is required between soil columns.

```
* EXAMPLE APPLICATION OF MILHY3
START               00.00 0 0
* OBSERVED INFLOW AT UNTER-SCHWARZ
STORE HYD           ID=1 NHD=404 DT=2.0 DA=181 SQ MI  BSF=0
                    FLOW RATES(CFS)= 0 0 0 0 0 0 0 0 0 0 0 0 0
                    9 58 144 268 422 620 847 1073 1252 1349
                    1419 1467 1494 1503 1497 1475 1442 1401
                    1355 1305 1241 1166 1106 1053 120
* ++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
*  ROUTE HYDROGRAPH FROM UNTER-SCHWARZ THROUGH REACH 3 TO BAD HERSFELD
*  COMPUTE RATING CURVE FOR UNTER-SCHWARZ
COMPUTE RATING CURVE ID=1 IT=2 MR=0 VS NO=4 NO SEGS=3
                    MIN ELEV=708.7 MAX ELEV=738.2
                    CH SLP=0.0007  FLDPL SLP=0.0005
                    N=0.05 DIST=1312.4
                    N=-.03  DIST=1371.7
                    N=0.05 DIST=1420.9
                    DIST    ELEV
                       0.0  738.2
                       0.3  718.5
                    1312.4  715.2
                    1312.7  708.7
                    1358.3  708.7
                    1371.4  708.7
                    1371.7  715.2
                    1372.0  715.2
                    1420.6  718.5
                    1420.9  738.2
* COMPUTE RATING CURVE FOR BAD HERSFELD
COMPUTE RATING CURVE ID=2 IT=2 MR=0 VS=5 NO SEGS=3
                    MIN ELEV=637.6  MAX ELEV=657.6
                    CH SLP=0.006  FLDPLN SLP=0.0075
                    N=0.05 DIST=393.2
                    N=-.03 DIST=492.1
                    N=0.05 DIST=623.7
                    DIST   ELEV
                      0.0  657.6
                      0.4  651.3
                    390.4  651.3
                    390.8  651.6
                    393.0  651.6
                    393.2  651.3
                    393.7  650.9
                    406.8  644.4
                    410.1  642.7
                    413.4  641.1
                    416.7  639.8
                    420.0  639.8
                    423.2  639.8
                    426.5  639.8
                    429.8  639.4
                    433.1  639.1
                    436.4  639.1
                    439.6  638.8
                    442.9  636.2
                    446.2  638.5
                    449.5  638.1
                    452.8  638.1
```

```
                    456.0  637.8
                    459.3  637.6
                    462.6  638.1
                    465.9  639.4
                    469.2  641.7
                    472.4  643.4
                    475.7  645.0
                    479.0  646.3
                    482.3  648.0
                    485.6  649.0
                    488.9  650.0
                    492.1  650.9
                    495.4  651.9
                    508.5  652.6
                    524.9  652.2
                    574.2  652.2
                    590.6  652.6
                    607.0  652.6
                    623.4  625.2
                    623.7  655.5
COMPUTE TRAVEL TIME ID=1  REACH NO=3  NO VS=2
                    L=75443 FT  SLP=0.0006
                    MR=0
ROUTE               ID=1  HYD NO=405  INFLOW ID=1
                    DT=0.25HRS MR=0
*-----------------------------------------------------------------------
*  COMPUTE RUNOFF HYDROGRAPH FROM SUBCATCHMENT 405
COMPUTE HYD         ID=2  HYD NO=405  DT=0.5HRS  DA=152.2 SQ MI
                    CN=90  HT=72.4 FT  L=20.4 MI
                    CUMULATIVE RAINFALL(INCHES) = 0.0 0.0 0.0 0.009 0.02
                    0.03 0.041 0.051 0.062 0.072 0.082 0.093 0.103
                    0.114 0.124 0.134 0.145 0.155 0.166 0.176 0.187
                    0.197 0.207 0.218 0.228 0.239 0.249 0.259 0.270
                    0.280 0.291 0.301 0.312 0.322 0.332 0.343 0.353
                    0.364 0.374 0.384 0.395 0.405 0.416 0.426 0.437
                    0.447 0.457 0.468 0.478 0.489 0.499 2.0
PRINT HYD           ID=2 NPK=0 IDR=0 IN=0
* ---------------------------------------------------------------------
* COMPUTE OUTFLOW HYD FROM SUBCATCHMENT 405 FROM FULDA RIVER BAD HERSFELD
ADD HYD             ID=1  HYD NO=405  ID=1  ID=2
PRINT HYD           ID=1
* ++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
* ++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
* OBSERVED INFLOW FOR RIVER HANE AT BAD HERSFELD
STORE HYD           ID=2 NHD=408 DT=2.0 DA=27 SQ MI BSF=0
                    FLOW RATES(CFS)=0 0 0 0 0 0 0 0 0 0 0 0 0
                    42 1593 4247 2777 1993 1481 1176 1010
                    902 817 743 674 609 549 492 440 394 354
                    315 288 259 234 212 192
* +++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
* ADD HYGROGRAPHS FROM FULDA AND HAUNE RIVERS AT BAD HERSFELD
ADD HYD             ID=1  HYD NO=1  INFLOW ID=1  ID=2
* ++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
* ROUTE OUTFLOW HYDROGRAPH AT BAD HERSFELD THROUGH REACH 6
* COMPUTE RATING CURVE FROM BAD HERSFELD
COMPUTE RATING CURVE ID=1  IT=2 MR=1 VS=5 NO SEGS=3
                    MIN ELEV=637.6  MAX ELEV=657.6
                    CH SLP=0.006  FLDPLN SLP=0.0075
```

```
                    N=0.05 DIST=393.2
                    N=-.03 DIST=492.1
                    N=0.05 DIST=623.7
                    DIST   ELEV
                    0.0    657.6
                      0.4  651.3
                    390.4  651.3
                    390.8  651.6
                    393.0  651.6
                    393.2  651.3
                    393.7  650.9
                    406.8  644.4
                    410.1  642.7
                    413.4  641.1
                    416.7  639.8
                    420.0  639.8
                    423.2  639.8
                    426.5  639.8
                    429.8  639.4
                    433.1  639.1
                    436.4  639.1
                    439.6  638.8
                    442.9  636.2
                    446.2  638.5
                    449.5  638.1
                    452.8  638.1
                    456.0  637.8
                    459.3  637.6
                    462.6  638.1
                    465.9  639.4
                    469.2  641.7
                    472.4  643.4
                    475.7  645.0
                    479.0  646.3
                    482.3  648.0
                    485.6  649.0
                    488.9  650.0
                    492.1  650.9
                    495.4  651.9
                    508.5  652.6
                    524.9  652.2
                    574.2  652.2
                    590.6  652.6
                    607.0  652.6
                    623.4  625.2
                    623.7  655.5
* COMPUTE RATING CURVE FOR ROTENBURG
COMPUTE RATING CURVE ID=2 IT=2 MR=1 VS=8 NO SEGS=3 MIN ELEV= 587.3
                    MAX ELEV=618.1  CH SLP= 0.006 FLDPN SLP=0.0075
                    N=0.05  DIST=1056.4  N=-0.03  DIST=1191.0
                    N=0.05  DIST=1253.6
                    DIST    ELEV
                       0.0  616.8
                       0.3  608.5
                      82.0  602.6
                     180.5  603.2
                     278.9  604.4
                     475.7  604.4
```

```
                        574.1  603.0
                        771.0  603.6
                        918.6  603.5
                       1056.4  604.8
                       1070.0  601.0
                       1099.1  599.6
                       1112.2  597.4
                       1118.8  595.4
                       1125.3  591.2
                       1131.9  591.0
                       1138.5  590.4
                       1145.0  589.6
                       1151.6  588.9
                       1158.1  588.4
                       1164.7  587.6
                       1171.3  587.3
                       1177.8  591.9
                       1184.4  595.1
                       1191.0  599.4
                       1197.5  602.0
                       1204.1  603.7
                       1215.6  611.5
                       1230.3  610.7
                       1233.6  611.2
                       1253.3  611.6
                       1253.6  618.1
* LEFT FLOODPLAIN
COMPUTE TRAVEL TIME    ID=3  REACH NO=6 NO VS=2
                       L=55808FT SLP=0.0006
                       MR=1 INRC=11 LRC=21
ROUTE                  ID=3 NHD=409 IDH=1
                       DT=0.25 MR=1
* CHANNEL
COMPUTE TRAVEL TIME    ID=4 REACH NO=6 NO VS=2
                       L=72550FT SLP=0.0007
                       MR=1 INRC=12 LRC=22
ROUTE                  ID=4 NHD=409 IDH=1
                       DT=0.25 MR=1
* RIGHT FLOODPLAIN
COMPUTE TRAVEL TIME    ID=5 REACH NO=6 NO VS=2
                       L=55808 FT SLP=0.0006
                       MR=1 INRC=13 LRC=23
ROUTE                  ID=5  NHD=409 IDH=1
                       DT=0.25HRS MR=1
ADD HYD                ID=1 NHD=409 IDI=3 IDII=4
ADD HYD                ID=1 NHD=409 IDI=1 IDII=5
* ---------------------------------------------------------------
* COMPUTE RUNOFF HYDROGRAPH FOR SUBCATCHMENT 409
COMPUTE HYD            ID=2  HYD NO=409  DT=0.5HRS  DA=155.5
                       CN=0 HT=48.9FT L=15.1 MI
                       CUMULATIVE RAINFALL(INCHES) = 0.0 0.0 0.0 0.009 0.02
                       0.03 0.041 0.051 0.062 0.072 0.082 0.093 0.103
                       0.114 0.124 0.134 0.145 0.155 0.166 0.176 0.187
                       0.197 0.207 0.218 0.228 0.239 0.249 0.259 0.270
                       0.280 0.291 0.301 0.312 0.322 0.332 0.343 0.353
                       0.364 0.374 0.384 0.395 0.405 0.416 0.426 0.437
                       0.447 0.457 0.468 0.478 0.489 0.499 2.0
* ---------------------------------------------------------------
```

```
* COMPUTE OUTFLOW HYDROGRAPH FROM SUBCATCHMENT 409, ROTENBURG
ADD HYD             ID=1  HYD NO=409  ID=1  ID=2
PRINT HYD           ID=1 NPK=2 IDR=2 IN=0
FINISH
```

```
00.00 00.00 25.50 25.50
1
10. 0.25
4
86.5
10 4 2
0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15  0.15
0.0 0.0 0.0
0.37 0.0 0.37 0.0 0.37 0.0
3.3E-5 0.0 3.3E-5 0.0 3.3E-5 0.0
0.3 0 3 0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3
0.0
10
0.057 0.067 0.076 0.093 0.12 0.15 0.19 0.23 0.28 0.37
-150. -100. -70. -40. -20. -10. -6. -3.3 -2. -.2
0.0
0.057 0.067 0.076 0.093 0.12 0.15 0.19 0.23 0.28 0.37
-150. -100. -70. -40. -20. -10. -6. -3.3 -2. -.2
0.0
0.057 0.067 0.076 0.093 0.12 0.15 0.19 0.23 0.28 0.37
-150. -100. -70. -40. -20. -10. -6. -3.3 -2. -.2
0.0
2.0
10 4 2
0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15
0.0 0.0 0.0
0.51 0.0 0.51 0.0 0.51 0.0
4.2E-6 0.0 4.2E-6 0.0 4.2E 6 0.0
0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3
0.0
10
0.064 0.075 0 085 0.11 0.14 0.17 0.21 0.26 0.32 0.51
-150. -100. -70. -40. -20. -10. -6. -3.3 -2. -.2
0.0
0.064 0.075 0.085 0.11 0.14 0.17 0.21 0.26 0.32 0.51
-150. -100. -70. -40. -20. -10. -6. -3.3 -2. -.2
0.0
0.064 0.075 0.085 0.11 0.14 0.17 0.21 0.26 0.32 0.51
-150. -100. -70. -40. -20. -10. -6. -3.3 -2. -.2
0.0
4.8
10 4 2
0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15
0.0 0.0 0.0
0.37 0.0 0.37 0.0 0.37 0.0
6.9E-6 0.0 6.9E-6 0.0 6.9E-6 0.0
0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3
0.0
10
0.058 0.067 0.077 0.094 0.12 0.16 0.19 0.23 0.28 0.37
-150. -100. -70. -40. -20. -10. -6. -3.3 -2. -.2
0.0
0.058 0.067 0.077 0.094 0.12 0.16 0.19 0.23 0.28 0.37
-150. -100. -70. -40. -20. -10. -6. -3.3 -2. -.2
0.0
0.058 0.067 0.077 0.094 0.12 0.16 0.19 0.23 0.28 0.37
-150. -100. -70. -40. -20. -10. -6. -3.3 -2. -.2
0.0
```

```
8.6
10 4 2
0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15
0.0 0.0 0.0
0.37 0.0 0.37 0.0 0.37 0.0
3.6E-5 0.0 3.6E-5 0.0 3.6E-5 0.0
0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3
0.0
10
0.057 0.066 0.076 0.093 0.12 0.15 0.19 0.23 0.28 0.37
-150. -100. -70. -40. -20. -10. -6. -3.3 -2. -.2
0.0
0.057 0.066 0.076 0.093 0.12 0.15 0.19 0.23 0.28 0.37
-150. -100. -70. -40. -20. -10. -6. -3.3 -2. -.2
0.0
0.057 0.066 0.076 0.093 0.12 0.15 0.19 0.23 0.28 0.37
-150. -100. -70. -40. -20. -10. -6. -3.3 -2. -.2
0.0
```

```
* EXAMPLE APPLICATION OF MILHY3
START                 00.00 0 0
* OBSERVED INFLOW AT UNTER-SCHWARZ
STORE HYD             ID=1 NHD=404 DT=2.0 DA=181 SQ MI  BSF=0
                      FLOW RATES(CFS)= 0 0 0 0 0 0 0 0 0 0 0 0 0
                      9 58 144 268 422 620 847 1073 1252 1349
                      1419 1467 1494 1503 1497 1475 1442 1401
                      1355 1305 1241 1166 1106 1053 120
* ++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
*  ROUTE HYDROGRAPH FROM UNTER-SCHWARZ THROUGH REACH 3 TO BAD HERSFELD
*  COMPUTE RATING CURVE FOR UNTER-SCHWARZ
COMPUTE RATING CURVE ID=1 IT=2 MR=0 VS NO=4 NO SEGS=3
                      MIN ELEV=708.7 MAX ELEV=738.2
                      CH SLP=0.0007  FLDPL SLP=0.0005
                      N=0.05 DIST=1312.4
                      N=-.03  DIST=1371.7
                      N=0.05 DIST=1420.9
                      DIST    ELEV
                         0.0  738.2
                         0.3  718.5
                      1312.4  715.2
                      1312.7  708.7
                      1358.3  708.7
                      1371.4  708.7
                      1371.7  715.2
                      1372.0  715.2
                      1420.6  718.5
                      1420.9  738.2
                                    MOMENTUM EXCHANGE METHOD      2
                                    RATING CURVE VALLEY SECTION   4.0
                                       WATER     FLOW      FLOW
                                      SURFACE    AREA      RATE
                                       ELEV      SQ FT     CFS
                                      708.70      0.00      0.00
                                      710.25     91.25    155.05
                                      711.81    182.72    477.37
                                      713.36    274.42    911.35
                                      714.91    366.33   1431.72
                                      716.46    787.68   2229.63
                                      718.02   2185.81   4170.07
                                      719.57   4342.65   8410.09
                                      721.12   6547.91  14670.48
                                      722.67   8753.25  22488.20
                                      724.23  10958.65  31705.05
                                      725.78  13164.14  42210.93
                                      727.33  15369.69  53922.54
                                      728.88  17575.32  66773.54
                                      730.44  19781.03  80709.19
                                      731.99  21986.80  95683.22
                                      733.54  24192.65 111655.61
                                      735.09  26398.57 128591.32
                                      736.65  28604.57 146459.20
                                      738.20  30810.64 165231.38
* COMPUTE RATING CURVE FOR BAD HERSFELD
COMPUTE RATING CURVE ID=2 IT=2 MR=0 VS=5 NO SEGS=3
                      MIN ELEV=637.6  MAX ELEV=657.6
                      CH SLP=0.006   FLDPLN SLP=0.0075
                      N=0.05 DIST=393.2
```

N= .03 DIST=492.1
N=0.05 DIST=623.7

DIST	ELEV
0.0	657.6
0.4	651.3
390.4	651.3
390.8	651.6
393.0	651.6
393.2	651.3
393.7	650.9
406.8	644.4
410.1	642.7
413.4	641.1
416.7	639.8
420.0	639.8
423.2	639 8
426.5	639.8
429.8	639.4
433.1	639.1
436.4	639.1
439.6	638.8
442.9	636.2
446.2	638.5
449.5	638.1
452.8	638.1
456.0	637.8
459.3	637.6
462.6	638.1
465.9	639.4
469.2	641.7
472.4	643.4
475.7	645.0
479.0	646.3
482.3	648.0
485.6	649.0
488.9	650.0
492.1	650.9
495.4	651.9
508.5	652.6
524.9	652.2
574.2	652.2
590.6	652.6
607.0	652.6
623.4	625.2
623.7	655.5

MOMENTUM EXCHANGE METHOD 2

RATING CURVE VALLEY SECTION 5.0

WATER SURFACE ELEV	FLOW AREA SQ FT	FLOW RATE CFS
637.60	0.00	0.00
638.65	74.59	273.51
639.71	116.87	498.71
640.76	179.74	934.63
641.81	248.52	1601.59
642.86	322.18	2442.78
643.92	400.82	3457.09
644.97	484.55	4641.50

```
                                        646.02    573.72   5985.95
                                        647.07    668.42   7531.72
                                        648.13    768.22   9258.80
                                        649.18    874.00  11109.36
                                        650.23    986.35  13163.23
                                        651.28   1105.39  15542.64
                                        652.34   1645.10  19138.52
                                        653.39   2293.44  25218.43
                                        654.44   2949.69  32899.45
                                        655.49   3606.02  41818.87
                                        656.55   4262.43  51889.83
                                        657.60   4918.91  63025.47
    COMPUTE TRAVEL TIME  ID=1  REACH NO=3  NO VS=2
                         L=75443 FT  SLP=0.0006
                         MR=0
0                                        TRAVEL TIME TABLE
                                              REACH  3.0

                                         WATER     FLOW     TRAVEL
                                         DEPTH     RATE      TIME
                                         FEET      CFS       HRS
                                          1.59      274.      7.64
                                          2.64      499.      6.39
                                          3.94      935.      5.14
                                          5.38     1602.      4.61
                                          6.60     2443.      5.42
                                          7.53     3457.      6.28
                                          8.43     4642.      6.57
                                          9.20     5986.      6.45
                                         10.01     7532.      6.35
                                         10.80     9259.      6.12
                                         11.56    11109.      5.82
                                         12.34    13163.      5.57
                                         13.14    15543.      5.33
                                         14.02    19139.      5.18
                                         15.11    25218.      4.86
                                         16.27    32899.      4.51
                                         17.46    41819.      4.18
                                         18.65    51890.      3.89
                                         19.87    63025.      3.63
    ROUTE                ID=1  HYD NO=405  INFLOW ID=1
                         DT=0.25HRS MR=0
    CHECK- VOLUME OF OUTFLOW HYDROGRAPH 1 IS   100.000% OF INFLOW HYDROGRAPH 1
    *----------------------------------------------------------------------
    *  COMPUTE RUNOFF HYDROGRAPH FROM SUBCATCHMENT 405
    COMPUTE HYD          ID=2  HYD NO=405  DT=0.5HRS  DA=152.2 SQ MI
                         CN=90  HT=72.4 FT  L=20.4 MI
                         CUMULATIVE RAINFALL(INCHES) = 0.0 0.0 0.0 0.009 0.02
                         0.03 0.041 0.051 0.062 0.072 0.082 0.093 0.103
                         0.114 0.124 0.134 0.145 0.155 0.166 0.176 0.187
                         0.197 0.207 0.218 0.228 0.239 0.249 0.259 0.270
                         0.280 0.291 0.301 0.312 0.322 0.332 0.343 0.353
                         0.364 0.374 0.384 0.395 0.405 0.416 0.426 0.437
                         0.447 0.457 0.468 0.478 0.489 0.499 2.0
Shape constant, N =  2.470
Unit peak =     1453.5 cms

    PRINT HYD            ID=2 NPK=0 IDR=0 IN=0
```

```
PRINT HYD           ID=2    NPK=0
0         HYDROGRAPH VOLUME=          329554912. CF
          PEAK        DISCHARGE  RATE=     1588.CFS



     * -------------------------------------------------------------------
     * COMPUTE OUTFLOW HYD FROM SUBCATCHMENT 405 FROM FULDA RIVER BAD HERSFELD
     ADD HYD              ID=1  HYD NO=405  ID=1  ID=2
     PRINT HYD            ID=1
PRINT HYD           ID=1    NPK=0
0         HYDROGRAPH VOLUME=          238953904. CF
          PEAK        DISCHARGE  RATE=     1591.CFS



     * ++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
     * ++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
     * OBSERVED INFLOW FOR RIVER HANE AT BAD HERSFELD
     STORE HYD            ID=2 NHD=408 DT=2.0 DA=27 SQ MI BSF=0
                          FLOW RATES(CFS)=0 0 0 0 0 0 0 0 0 0 0 0 0
                          42 1593 4247 2777 1993 1481 1176 1010
                          902 817 743 674 609 549 492 440 394 354
                          315 288 259 234 212 192
     * +++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
     * ADD HYGROGRAPHS FROM FULDA AND HAUNE RIVERS AT BAD HERSFELD
     ADD HYD              ID=1  HYD NO=1  INFLOW ID=1  ID=2
     * ++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
     * ROUTE OUTFLOW HYDROGRAPH AT BAD HERSFELD THROUGH REACH 6
     * COMPUTE RATING CURVE FROM BAD HERSFELD
     COMPUTE RATING CURVE ID=1  IT=2 MR=1 VS=5 NO SEGS=3
                          MIN ELEV=637.6  MAX ELEV=657.6
                          CH SLP=0.006  FLDPLN SLP=0.0075
                          N=0.05 DIST=393.2
                          N=-.03 DIST=492.1
                          N=0.05 DIST=623.7
                          DIST   ELEV
                          0.0    657.6
                            0.4  651.3
                          390.4  651.3
                          390.8  651.6
                          393.0  651.6
                          393.2  651.3
                          393.7  650.9
                          406.8  644.4
                          410.1  642.7
                          413.4  641.1
                          416.7  639.8
                          420.0  639.8
                          423.2  639.8
                          426.5  639.8
                          429.8  639.4
                          433.1  639.1
                          436.4  639.1
                          439.6  638.8
                          442.9  636.2
                          446.2  638.5
                          449.5  638.1
```

452.8	638.1
456.0	637.8
459.3	637.6
462.6	638.1
465.9	539.4
469.2	641.7
472.4	643.4
475.7	645.0
479.0	646.3
482.3	648.0
485.6	649.0
488.9	650.0
492.1	650.9
495.4	651.9
508.5	652.6
524.9	652.2
574.2	652.2
590.6	652.6
607.0	652.6
623.4	625.2
623.7	655.5

MOMENTUM EXCHANGE METHOD 2

RATING CURVE FOR SEGMENT 11

WATER SURFACE ELEV	FLOW AREA SQ FT	FLOW RATE CFS
637.60	0.0	0.0
638.65	0.0	0.0
639.71	0.0	0.0
640.76	0.0	0.0
641.81	0.0	0.0
642.86	0.0	0.0
643.92	0.0	0.0
644.97	0.0	0.0
646.02	0.0	0.0
647.07	0.0	0.0
648.13	0.0	0.0
649.18	0.0	0.0
650.23	0.0	0.0
651.28	0.0	0.0
652.34	406.4	1066.0
653.39	820.0	3427.8
654.44	1233.7	6758.8
655.49	1647.4	10925.3
656.55	2061.1	15844.1
657.60	2475.0	21456.1

RATING CURVE FOR SEGMENT 12

WATER SURFACE ELEV	FLOW AREA SQ FT	FLOW RATE CFS
637.60	0.0	0.0
638.65	19.5	62.0
639.71	52.9	239.7
640.76	106.1	621.9
641.81	164.6	1228.8
642.86	227.3	2003.1
643.92	294.3	2943.6
644.97	365.7	4046.8

646.02	441.8	5302.6
647.07	522.9	6751.8
648.13	608.3	8374.2
649.18	699.1	10111.7
650.23	795.7	12043.9
651.28	898.2	14309.2
652.34	1002.3	17176.2
653.39	1106.4	20251.5
654.44	1210.5	23526.1
655.49	1314.6	26994.1
656.55	1418.7	30650.3
657.60	1522.8	34489.9

RATING CURVE FOR SEGMENT 13

WATER SURFACE ELEV	FLOW AREA SQ FT	FLOW RATE CFS
637.60	0.0	0.0
638.65	55.1	211.5
639.71	64.0	259.1
640.76	73.6	312.7
641.81	83.9	372.8
642.86	94.9	439.7
643.92	106.6	513.6
644.97	118.9	594.9
646.02	131.9	683.7
647.07	145.6	780.4
648.13	159.9	885.1
649.18	174.9	998.3
650.23	190.6	1120.1
651.28	207.2	1234.4
652.34	236.4	897.5
653.39	367.1	1540.7
654.44	505.6	2616.6
655.49	644.1	3902.1
656.55	782.6	5398.8
657.60	921.1	7083.8

% DISCHARGE IN SEGMENT 11

ELEV	PERCENT
637.60	0.000
638.65	0.000
639.71	0.000
640.76	0.000
641.81	0.000
642.86	0.000
643.92	0.000
644.97	0.000
646.02	0.000
647.07	0.000
648.13	0.000
649.18	0.000
650.23	0.000
651.28	0.000
652.34	0.056
653.39	0 136
654.44	0.205
655.49	0.261
656.55	0.305
657.60	0.340

```
% DISCHARGE IN SEGMENT  12
     ELEV      PERCENT
    637.60      0.000
    638.65      0.227
    639.71      0.481
    640.76      0.665
    641.81      0.767
    642.86      0.820
    643.92      0.851
    644.97      0.872
    646.02      0.886
    647.07      0.896
    648.13      0.904
    649.18      0.910
    650.23      0.915
    651.28      0.921
    652.34      0.897
    653.39      0.803
    654.44      0.715
    655.49      0.645
    656.55      0.591
    657.60      0.547
% DISCHARGE IN SEGMENT  13
     ELEV      PERCENT
    637.60      0.000
    638.65      0.773
    639.71      0.519
    640.76      0.335
    641.81      0.233
    642.86      0.180
    643.92      0.149
    644.97      0.128
    646.02      0.114
    647.07      0.104
    648.13      0.096
    649.18      0.090
    650.23      0.085
    651.28      0.079
    652.34      0.047
    653.39      0.061
    654.44      0.080
    655.49      0.093
    656.55      0.104
    657.60      0.112
* COMPUTE RATING CURVE FOR ROTENBURG
COMPUTE RATING CURVE ID=2 IT=2 MR=1 VS=8 NO SEGS=3 MIN ELEV= 587.3
                     MAX ELEV=618.1  CH SLP= 0.006 FLDPN SLP=0.0075
                     N=0.05  DIST=1056.4  N=-0.03  DIST=1191.0
                     N=0.05  DIST=1253.6
                     DIST    ELEV
                        0.0  616.8
                        0.3  608.5
                       82.0  602.6
                      180.5  603.2
                      278.9  604.4
                      475.7  604.4
                      574.1  603.0
                      771.0  603.6
```

918.6	603.5
1056.4	604.8
1070.0	601.0
1099.1	599.6
1112.2	597.4
1118.8	595.4
1125.3	591.2
1131.9	591.0
1138.5	590.4
1145.0	589.6
1151.6	588.9
1158.1	588.4
1164.7	587.6
1171.3	587.3
1177.8	591.9
1184.4	595.1
1191.0	599.4
1197.5	602.0
1204.1	603.7
1215.6	611.5
1230.3	610.7
1233.6	611.2
1253.3	611.6
1253.6	618.1

MOMENTUM EXCHANGE METHOD 2

RATING CURVE FOR SEGMENT 21

WATER SURFACE ELEV	FLOW AREA SQ FT	FLOW RATE CFS
587.30	0.0	0.0
588.92	0.0	0.0
590.54	0.0	0.0
592.16	0.0	0.0
593.78	0.0	0.0
595.41	0.0	0.0
597.03	0.0	0.0
598.65	0.0	0.0
600.27	0.0	0.0
601.89	0.0	0.0
603.51	121.8	152.7
605.13	1409.2	4525.1
606.75	3063.7	16270.9
608.37	4754.6	33365.7
609.99	6466.5	55591.0
611.62	8178.7	82144.9
613.24	9890.9	112649.2
614.86	11603.2	146844.9
616.48	13315.5	184526.2
618.10	15028.0	225706.0

RATING CURVE FOR SEGMENT 22

WATER SURFACE ELEV	FLOW AREA SQ FT	FLOW RATE CFS
587.30	0.0	0.0
588.92	19.4	66.9
590.54	69.1	380.6
592.16	148.8	1088.7
593.78	242.0	2271.4

595.41	344.6	3833.1
597.03	458.1	5703.2
598.65	586.3	7838.2
600.27	736.8	9973.5
601.89	928.8	13238.6
603.51	1134.8	17935.1
605.13	1350.0	23407.8
606.75	1568.2	30047.3
608.37	1786.4	37333.6
609.99	2004.6	45239.2
611.62	2222.8	53740.6
613.24	2440.9	62817.6
614.86	2659.1	72452.5
616.48	2877.3	82629.6
618.10	3095.5	93334.8

RATING CURVE FOR SEGMENT 23

WATER SURFACE ELEV	FLOW AREA SQ FT	FLOW RATE CFS
587.30	0.0	0.0
588.92	0.0	0.0
590.54	0.0	0.0
592.16	0.0	0.0
593.78	0.0	0.0
595.41	0.0	0.0
597.03	0.0	0.0
598.65	0.0	0.0
600.27	0.9	0.9
601.89	7.7	19.0
603.51	22.7	78.1
605.13	45.4	216.4
606.75	72.0	422.7
608.37	102.4	698.3
609.99	136.8	1047.5
611.62	189.0	970.1
613.24	290.1	1949.6
614.86	391.2	3160.6
616.48	492.5	4569.2
618.10	593.9	6150.5

% DISCHARGE IN SEGMENT 21

ELEV	PERCENT
587.30	0.000
588.92	0.000
590.54	0.000
592.16	0.000
593.78	0.000
595.41	0.000
597.03	0.000
598.65	0.000
600.27	0.000
601.89	0.000
603.51	0.008
605.13	0.161
606.75	0.348
608.37	0.467
609.99	0.546
611.62	0.600
613.24	0.635

614.86	0.660
616.48	0.679
618.10	0.694

% DISCHARGE IN SEGMENT 22

ELEV	PERCENT
587.30	0.000
588.92	1.000
590.54	1.000
592.16	1.000
593.78	1.000
595.41	1.000
597.03	1.000
598.65	1.000
600.27	1.000
601.89	0.999
603.51	0.987
605.13	0.832
606.75	0.643
608.37	0.523
609.99	0.444
611.62	0.393
613.24	0.354
614.86	0.326
616.48	0.304
618.10	0.287

% DISCHARGE IN SEGMENT 23

ELEV	PERCENT
587.30	0.000
588.92	0.000
590.54	0.000
592.16	0.000
593.78	0.000
595.41	0.000
597.03	0.000
598.65	0.000
600.27	0.000
601.89	0.001
603.51	0.004
605.13	0.008
606.75	0.009
608.37	0.010
609.99	0.010
611.62	0.007
613.24	0.011
614.86	0.014
616.48	0.017
618.10	0.019

```
* LEFT FLOODPLAIN
COMPUTE TRAVEL TIME  ID=3  REACH NO=6 NO VS=2
                     L=55808FT SLP=0.0006
                     MR=1 INRC=11 LRC=21
0                 MULTIPLE ROUTING INVOKED
0                                     TRAVEL TIME TABLE
                                              REACH  6.0

                                      WATER     FLOW     TRAVEL
                                      DEPTH     RATE      TIME
                                      FEET      CFS       HRS
```

```
                                         2.23      1066.      19.44
                                         2.84      3428.       7.39
                                         3.49      6759.       4.52
                                         4.17     10925.       3.32
                                         4.87     15844.       2.67
                                         5.60     21456.       2.28
    ROUTE            ID=3 NHD=409 IDH=1
                     DT=0.25 MR=1
0                                INFLOW FOR SEGMENT    1
                        HOURS    PERCENT     CFS
 NO FLOW IN SEGMENT
    * CHANNEL
    COMPUTE TRAVEL TIME  ID=4 REACH NO=6 NO VS=2
                     L=72550FT SLP=0.0007
                     MR=1 INRC=12 LRC=22
0                 MULTIPLE ROUTING INVOKED
0                                      TRAVEL TIME TABLE
                                              REACH  6.0

                                        WATER     FLOW     TRAVEL
                                        DEPTH     RATE      TIME
                                        FEET      CFS       HRS
                                         1.98       62.      6.10
                                         3.01      240.      4.19
                                         4.18      622.      3.28
                                         5.33     1229.      2.66
                                         6.39     2003.      2.25
                                         7.45     2944.      1.99
                                         8.53     4047.      1.80
                                         9.60     5303.      1.66
                                        10.70     6752.      1.56
                                        11.84     8374.      1.48
                                        13.01    10112.      1.44
                                        14.01    12044.      1.38
                                        15.02    14309.      1.32
                                        16.04    17176.      1.23
                                        17.04    20251.      1.16
                                        18.05    23526.      1.10
                                        19.00    26994.      1.04
                                        19.97    30650.      0.99
                                        20.92    34490.      0.94
    ROUTE            ID=4 NHD=409 IDH=1
                     DT=0.25 MR=1
0                                INFLOW FOR SEGMENT    2
                        HOURS    PERCENT     CFS
                         3.250    0.000     0.000
                         3.500    0.001     0.001
                         3.750    0.004     0.016
                         4.000    0.009     0.101
                         4.250    0.019     0.427
                         4.500    0.035     1.460
                         4.750    0.059     4.135
                         5.000    0.090     9.821

    ..........route...../continued


                        56.000    0.790  1547.975
```

56.250	0.789	1538.240
56.500	0.788	1528.520
56.750	0.788	1518.594
57.000	0.787	1508.691
57.250	0.786	1498.587
57.500	0.786	1488.507
57.750	0.785	1478.244
58.000	0.784	1467.999

CHECK- VOLUME OF OUTFLOW HYDROGRAPH 4 IS 78.449% OF INFLOW HYDROGRAPH 1

* RIGHT FLOODPLAIN

COMPUTE TRAVEL TIME ID=5 REACH NO=6 NO VS=2
L=55808 FT SLP=0.0006
MR=1 INRC=13 LRC=23

0 MULTIPLE ROUTING INVOKED

0 TRAVEL TIME TABLE
REACH 6.0

WATER DEPTH FEET	FLOW RATE CFS	TRAVEL TIME HRS
8.04	19.	18.61
9.17	78.	6.84
10.73	216.	3.98
12.67	423.	3.06
14.98	698.	2.62
17.50	1047.	2.35
16.98	970.	2.40
21.21	1950.	2.82
22.57	3161.	2.34
23.92	4569.	2.03
25.26	6151.	1.81

ROUTE ID=5 NHD=409 IDH=1
DT=0.25HRS MR=1

0 INFLOW FOR SEGMENT 3

HOURS	PERCENT	CFS
3.250	0.000	0.000
3.500	0.003	0.004
3.750	0.013	0.056
4.000	0 031	0.346
4.250	0.064	1.456
4.500	0.119	4.983
4.750	0.200	14.117
5.000	0.308	33.529

..........route......./continued

55.750	0.210	413.179
56.000	0.210	412.213
56.250	0.211	411.275
56.500	0.212	410.324
56.750	0.212	409.336
57.000	0.213	408.328
57.250	0.214	407.291
57.500	0.214	406.233
57.750	0.215	405.141
58.000	0.216	404.035

CHECK- VOLUME OF OUTFLOW HYDROGRAPH 5 IS 20.180% OF INFLOW HYDROGRAPH 1

```
ADD HYD              ID=1 NHD=409 IDI=3 IDII=4
ADD HYD              ID=1 NHD=409 IDI=1 IDII=5
* ---------------------------------------------------------------
* COMPUTE RUNOFF HYDROGRAPH FOR SUBCATCHMENT 409
COMPUTE HYD          ID=2  HYD NO=409  DT=0.5HRS  DA=155.5
                     CN=0 HT=48.9FT L=15.1 MI
                     CUMULATIVE RAINFALL(INCHES) = 0.0 0.0 0.0 0.009 0.02
                     0.03 0.041 0.051 0.062 0.072 0.082 0.093 0.103
                     0.114 0.124 0.134 0.145 0.155 0.166 0.176 0.187
                     0.197 0.207 0.218 0.228 0.239 0.249 0.259 0.270
                     0.280 0.291 0.301 0.312 0.322 0.332 0.343 0.353
                     0.364 0.374 0.384 0.395 0.405 0.416 0.426 0.437
                     0.447 0.457 0.468 0.478 0.489 0.499 2.0
```

Shape constant, N = 2.411
Unit peak = 1495.6 cms

INCREMENTAL RUNOFF-Parameter variability included

SD of detcap 0.000
SD of saturated soil content0.000 layer 1
0.000 layer 2
0.000 layer 3
SD of suction moisture curve0.000 layer 1
0.000 layer 2
0.000 layer 3
SD of sat conductivity0.000 layer 1
0.000 layer 2
0.000 layer 3
SD of initial water content0.000
0GENERATED K-MOISTURE CURVE
Millington-Quirk Method

Layer 1			Layer 2			Layer 3		
Moisture	Suction	Unsat K	Moisture	Suction	Unsat K	Moisture	Suction	Unsat K
0.057	-150.000	0.000000000023	0.057	-150.000	0.000000000023	0.057	-150.000	0.000000000023
0.073	-78.421	0.000000000144	0.073	-78.421	0.000000000144	0.073	-78.421	0.000000000144
0.090	-45.387	0.000000000553	0.090	-45.387	0.000000000553	0.090	-45.387	0.000000000553
0.106	-30.058	0.000000001621	0.106	-30.058	0.000000001621	0.106	-30.058	0.000000001621
0.123	-19.035	0.000000004190	0.123	-19.035	0.000000004190	0.123	-19.035	0.000000004190
0.139	-13.544	0.000000009711	0.139	-13.544	0.000000009711	0.139	-13.544	0.000000009711
0.156	-9.416	0.000000020796	0.156	-9.416	0.000000020796	0.156	-9.416	0.000000020796
0.172	-7.768	0.000000040196	0.172	-7.768	0.000000040196	0.172	-7.768	0.000000040196
0.189	-6.121	0.000000071057	0.189	-6.121	0.000000071057	0.189	-6.121	0.000000071057
0.205	-4.970	0.000000117721	0.205	-4.970	0.000000117721	0.205	-4.970	0.000000117721
0.222	-3.858	0.000000187038	0.222	-3.858	0.000000187038	0.222	-3.858	0.000000187038
0.238	-3.087	0.000000288406	0.238	-3.087	0.000000288406	0.238	-3.087	0.000000288406
0.255	-2.658	0.000000427721	0.255	-2.658	0.000000427721	0.255	-2.658	0.000000427721
0.271	-2.230	0.000000608825	0.271	-2.230	0.000000608825	0.271	-2.230	0.000000608825
0.288	-1.847	0.000000837452	0.288	-1.847	0.000000837452	0.288	-1.847	0.000000837452
0.304	-1.518	0.000001119370	0.304	-1.518	0.000001119370	0.304	-1.518	0.000001119370
0.321	-1.188	0.000001465874	0.321	-1.188	0.000001465874	0.321	-1.188	0.000001465874
0.337	-0.859	0.000001913219	0.337	-0.859	0.000001913219	0.337	-0.859	0.000001913219
0.354	-0.529	0.000002609657	0.354	-0.529	0.000002609657	0.354	-0.529	0.000002609657
0.370	-0.200	0.000005070084	0.370	-0.200	0.000005070084	0.370	-0.200	0.000005070084

0START CONDITIONS

Simulation start time 0.0hrs
Precipitation begins at 0.0 and ends at 25.5

Rainfall data time increment = 0.5000 hrs
Time increment for iteration period = 10.0 secs

Maximum evaporation during the day = 0.00000000 ms-1
Surface detention capacity = 0.0000 m

INITIAL SOIL COLUMN CONDITIONS

	SAT THETA m3/m3	SAT HYD COND ms-1	CELL NO	DEPTH m	INITAL THETA m3/m3	REL SAT
Layer 1	0.3710	0.000033000015	1	0.0750	0.3000	0.809
			2	0.2250	0.3000	0.809
			3	0.3750	0.3000	0.809
			4	0.5250	0.3000	0.809
Layer 2	0.3710	0.000033000015	5	0.6750	0.3000	0.809
			6	0.8250	0.3000	0.809
Layer 3	0.3710	0.000033000015	7	0.9750	0.3000	0.809
			8	1.1250	0.3000	0.809
			9	1.2750	0.3000	0.809
			10	1.4250	0.3000	0.809

0SOIL COLUMN CONDITIONS 0.500 HRS SINCE SIMULATION BEGAN

Cell	Depth	SWP	Theta	Hyd cond	Net flux	Rel sat
1	0.0750	-1.7490	0.2925	0.000000922	-0.000004233	0.788
2	0.2250	-1.6653	0.2967	0.000000993	-0.000003147	0.800
3	0.3750	-1.6249	0.2987	0.000001028	-0.000001820	0.805
4	0.5250	-1.6082	0.2996	0.000001042	-0.000000840	0.808
5	0.6750	-1.6023	0.2999	0.000001047	-0.000000317	0.808
6	0.8250	-1.6006	0.3000	0.000001049	-0.000000100	0.809
7	0.9750	-1.6001	0.3000	0.000001049	-0.000000027	0.809
8	1.1250	-1.6000	0.3000	0.000001049	-0.000000006	0.809
9	1.2750	-1.6000	0.3000	0.000001049	-0.000000002	0.809
10	1.4250	-1.6000	0.3000	0.000001049	0.000000000	0.809

0Balance check on soil column water status = -0.0000006
Balance check as column water vol. = 0.0001306 %

Cumulative evaporation = 0.00000000
Cumulative precipitation = 0.0000
Cumulative infiltration = 0.000000
Cumulative drainage = 0.001888

Detention capacity exceeded
Runoff total in the last period 0.0000000 m
Runoff total in the last period 0.0000000 ins 0.500

0SOIL COLUMN CONDITIONS 1.000 HRS SINCE SIMULATION BEGAN

Cell	Depth	SWP	Theta	Hyd cond	Net flux	Rel sat
1	0.0750	-1.8336	0.2883	0.000000849	-0.000003008	0.777
2	0.2250	-1.7342	0.2933	0.000000934	-0.000002608	0.790
3	0.3750	-1.6719	0.2964	0.000000988	-0.000001988	0.799
4	0.5250	-1.6356	0.2982	0.000001019	-0.000001338	0.804
5	0.6750	-1.6162	0.2992	0.000001035	-0.000000797	0.806
6	0.8250	-1.6068	0.2997	0.000001043	-0.000000421	0.808

```
    7  0.9750 -1.6026  0.2999   0.000001047  -0.000000199    0.808
    8  1.1250 -1.6009  0.3000   0.000001048  -0.000000084    0.808
    9  1.2750 -1.6003  0.3000   0.000001049  -0.000000033    0.809
   10  1.4250 -1.6001  0.3000   0.000001049  -0.000000014    0.809
0Balance check on soil column water status =  -0.0000016
 Balance check as  column water vol.   =  -0.0003621 %

 Cumulative evaporation   =   0.00000000
 Cumulative precipitation =   0.0000
 Cumulative infiltration  =   0.000000
 Cumulative drainage      =   0.003777

 Detention capacity exceeded
 Runoff total in the last period 0.0000000  m
 Runoff total in the last period 0.0000000  ins  1.000

0SOIL COLUMN CONDITIONS   1.500 HRS SINCE              SIMULATION BEGAN

  Cell  Depth    SWP    Theta    Hyd cond     Net flux     Rel sat
    1  0.0750 -1.8826  0.2861   0.000000816  -0.000001740    0.771
    2  0.2250 -1.7855  0.2907   0.000000890  -0.000001926    0.784
    3  0.3750 -1.7160  0.2942   0.000000950  -0.000001701    0.793
    4  0.5250 -1.6686  0.2966   0.000000990  -0.000001367    0.799
    5  0.6750 -1.6383  0.2981   0.000001016  -0.000000996    0.803
    6  0.8250 -1.6201  0.2990   0.000001032  -0.000000661    0.806
    7  0.9750 -1.6099  0.2995   0.000001041  -0.000000402    0.807
    8  1.1250 -1.6046  0.2998   0.000001045  -0.000000225    0.808
    9  1.2750 -1.6021  0.2999   0.000001047  -0.000000121    0.808
   10  1.4250 -1.6011  0.2999   0.000001048  -0.000000074    0.808
0Balance check on soil column water status =  -0.0000029
 Balance check as  column water vol.   =  -0.0006496 %

 Cumulative evaporation   =   0.00000000
 Cumulative precipitation =   0.0002
 Cumulative infiltration  =   0.000229
 Cumulative drainage      =   0.005664

 Detention capacity exceeded
 Runoff total in the last period 0.0000000  m
 Runoff total in the last period 0.0000000  ins  1.500

0SOIL COLUMN CONDITIONS   2.000 HRS SINCE              SIMULATION BEGAN

  Cell  Depth    SWP    Theta    Hyd cond     Net flux     Rel sat
    1  0.0750 -1.9232  0.2844   0.000000792  -0.000001402    0.766
    2  0.2250 -1.8270  0.2886   0.000000855  -0.000001601    0.778
    3  0.3750 -1.7541  0.2923   0.000000917  -0.000001488    0.788
    4  0.5250 -1.7005  0.2950   0.000000963  -0.000001286    0.795
    5  0.6750 -1.6628  0.2969   0.000000995  -0.000001034    0.800
    6  0.8250 -1.6375  0.2981   0.000001017  -0.000000775    0.804
    7  0.9750 -1.6214  0.2989   0.000001031  -0.000000544    0.806
    8  1.1250 -1.6117  0.2994   0.000001039  -0.000000362    0.807
    9  1.2750 -1.6064  0.2997   0.000001044  -0.000000238    0.808
   10  1.4250 -1.6040  0.2998   0.000001046  -0.000000174    0.808
0Balance check on soil column water status =  -0.0000039
 Balance check as  column water vol.   =  -0.0008873 %

 Cumulative evaporation   =   0.00000000
```

Cumulative precipitation = 0.0005
Cumulative infiltration = 0.000508
Cumulative drainage = 0.007549

Detention capacity exceeded
Runoff total in the last period 0.0000000 m
Runoff total in the last period 0.0000000 ins 2.000

..........compute hyd....../continued

0SOIL COLUMN CONDITIONS 25.000 HRS SINCE SIMULATION BEGAN

Cell	Depth	SWP	Theta	Hyd cond	Net flux	Rel sat
1	0.0750	-2.8489	0.2473	0.000000399	-0.000000422	0.667
2	0.2250	-2.7653	0.2506	0.000000429	-0.000000413	0.675
3	0.3750	-2.6916	0.2534	0.000000455	-0.000000409	0.683
4	0.5250	-2.6268	0.2559	0.000000481	-0.000000419	0.690
5	0.6750	-2.5701	0.2581	0.000000507	-0.000000433	0.696
6	0.8250	-2.5216	0.2599	0.000000530	-0.000000441	0.701
7	0.9750	-2.4816	0.2615	0.000000548	-0.000000452	0.705
8	1.1250	-2.4504	0.2627	0.000000562	-0.000000456	0.708
9	1.2750	-2.4288	0.2635	0.000000572	-0.000000460	0.710
10	1.4250	-2.4175	0.2639	0.000000578	-0.000000460	0.711

0Balance check on soil column water status = -0.0000430
Balance check as column water vol. = -0.0111281 %

Cumulative evaporation = 0.00000000
Cumulative precipitation = 0.0127
Cumulative infiltration = 0.012674
Cumulative drainage = 0.076113

Detention capacity exceeded
Runoff total in the last period 0.0000000 m
Runoff total in the last period 0.0000000 ins 25.000

0SOIL COLUMN CONDITIONS 25.500 HRS SINCE SIMULATION BEGAN

Cell	Depth	SWP	Theta	Hyd cond	Net flux	Rel sat
1	0.0750	-0.2656	0.3669	0.000004996	0.000031808	0.989
2	0.2250	-0.8816	0.3364	0.000002054	0.000070547	0.907
3	0.3750	-1.8334	0.2888	0.000000927	0.000072419	0.778
4	0.5250	-2.4233	0.2639	0.000000575	0.000027042	0.711
5	0.6750	-2.5476	0.2590	0.000000518	0.000005381	0.698
6	0.8250	-2.5302	0.2596	0.000000526	0.000000531	0.700
7	0.9750	-2.4948	0.2610	0.000000542	-0.000000298	0.703
8	1.1250	-2.4645	0.2621	0.000000556	-0.000000429	0.707
9	1.2750	-2.4430	0.2630	0.000000566	-0.000000450	0.709
10	1.4250	-2.4318	0.2634	0.000000571	-0.000000453	0.710

0Balance check on soil column water status = -0.0000434
Balance check as column water vol. = -0.0102382 %

Cumulative evaporation = 0.00000000
Cumulative precipitation = 0.0508
Cumulative infiltration = 0.050800
Cumulative drainage = 0.077147

Detention capacity exceeded

Runoff total in the last period 0.0000000 m

Runoff total in the last period 0.0000000 ins 25.500

* COMPUTE OUTFLOW HYDROGRAPH FROM SUBCATCHMENT 409, ROTENBURG

ADD HYD   ID=1 HYD NO=409 ID=1 ID=2

PRINT HYD   ID=1 NPK=2 IDR=2 IN=0

PRINT HYD   ID=1   NPK=2

TIME HRS	ELEV FT	TIME HRS	ELEV FT	TIME HRS	ELEV FT	TIME HRS	ELEV FT	TIME HRS	ELEV FT
0.000	587.300	15.000	590.303	30.000	594.314	45.000	593.921	60.000	592.550
0.250	587.300	15.250	590.228	30.250	594.612	45.250	593.916	60.250	592.436
0.500	587.300	15.500	590.155	30.500	594.819	45.500	593.912	60.500	592.325
0.750	587.300	15.750	590.090	30.750	594.969	45.750	593.907	60.750	592.226
1.000	587.300	16.000	590.033	31.000	595.069	46.000	593.902	61.000	592.115
1.250	587.300	16.250	589.982	31.250	595.127	46.250	593.897	61.250	591.974
1.500	587.300	16.500	589.935	31.500	595.154	46.500	593.892	61.500	591.846
1.750	587.300	16.750	589.891	31.750	595.155	46.750	593.887	61.750	591.731
2.000	587.300	17.000	589.850	32.000	595.135	47.000	593.882	62.000	591.616
2.250	587.300	17.250	589.811	32.250	595.109	47.250	593.876	62.250	591.492
2.500	587.300	17.500	589.774	32.500	595.082	47.500	593.871	62.500	591.358
2.750	587.300	17.750	589.739	32.750	595.046	47.750	593.865	62.750	591.225
3.000	587.300	18.000	589.705	33.000	595.004	48.000	593.858	63.000	591.111
3.250	587.300	18.250	589.672	33.250	594.956	48.250	593.852	63.250	591.016
3.500	587.300	18.500	589.640	33.500	594.904	48.500	593.846	63.500	590.935
3.750	587.300	18.750	589.610	33.750	594.850	48.750	593.839	63.750	590.864
4.000	587.300	19.000	589.564	34.000	594.794	49.000	593.832	64.000	590.799
4.250	587.301	19.250	589.505	34.250	594.742	49.250	593.825	64.250	590.738
4.500	587.303	19.500	589.453	34.500	594.696	49.500	593.818	64.500	590.682
4.750	587.309	19.750	589.408	34.750	594.651	49.750	593.811	64.750	590.633
5.000	587.324	20.000	589.370	35.000	594.607	50.000	593.803	65.000	590.589
5.250	587.362	20.250	589.336	35.250	594.563	50.250	593.795	65.250	590.549
5.500	587.440	20.500	589.306	35.500	594.520	50.500	593.788	65.500	590.474
5.750	587.567	20.750	589.272	35.750	594.477	50.750	593.778	65.750	590.400
6.000	587.745	21.000	589.232	36.000	594.434	51.000	593.767	66.000	590.334
6.250	587.967	21.250	589.196	36.250	594.395	51.250	593.756	66.250	590.270
6.500	588.245	21.500	589.167	36.500	594.362	51.500	593.745	66.500	590.206
6.750	588.520	21.750	589.144	36.750	594.330	51.750	593.734	66.750	590.140
7.000	588.959	22.000	589.124	37.000	594.300	52.000	593.722	67.000	590.076
7.250	589.081	22.250	589.106	37.250	594.271	52.250	593.710	67.250	590.016
7.500	589.243	22.500	589.090	37.500	594.243	52.500	593.698	67.500	589.960

7.750	589.463	22.750	589.076	37.750	594.215	52.750	593.686	67.750	589.907
8.000	589.678	23.000	589.062	38.000	594.189	53.000	593.674	68.000	589.858
8.250	589.851	23.250	589.049	38.250	594.165	53.250	593.661	68.250	589.811
8.500	590.023	23.500	589.037	38.500	594.145	53.500	593.648	68.500	589.767
8.750	590.200	23.750	589.026	38.750	594.126	53.750	593.635	68.750	589.725
9.000	590.382	24.000	589.015	39.000	594.108	54.000	593.622	69.000	589.686
9.250	590.521	24.250	589.008	39.250	594.092	54.250	593.609	69.250	589.648
9.500	590.562	24.500	589.005	39.500	594.077	54.500	593.595	69.500	589.613
9.750	590.581	24.750	589.003	39.750	594.062	54.750	593.582	69.750	589.579
10.000	590.603	25.000	589.003	40.000	594.049	55.000	593.568	70.000	589.547
10.250	590.622	25.250	589.017	40.250	594.037	55.250	593.554	70.250	589.516
10.500	590.633	25.500	589.051	40.500	594.027	55.500	593.540	70.500	589.486
10.750	590.633	25.750	589.139	40.750	594.018	55.750	593.526	70.750	589.458
11.000	590.628	26.000	589.261	41.000	594.010	56.000	593.511	71.000	589.432
11.250	590.622	26.250	589.412	41.250	594.001	56.250	593.497	71.250	589.406
11.500	590.615	26.500	589.662	41.500	593.993	56.500	593.482	71.500	589.381
11.750	590.608	26.750	589.895	41.750	593.986	56.750	593.468	71.750	589.358
12.000	590.599	27.000	590.183	42.000	593.979	57.000	593.454	72.000	589.336
12.250	590.590	27.250	590.555	42.250	593.972	57.250	593.439	72.250	589.314
12.500	590.581	27.500	590.773	42.500	593.967	57.500	593.425	72.500	589.293
12.750	590.570	27.750	591.026	42.750	593.962	57.750	593.410	72.750	589.273
13.000	590.560	28.000	591.299	43.000	593.957	58.000	593.395	73.000	589.254
13.250	590.548	28.250	591.643	43.250	593.952	58.250	593.342	73.250	589.236
13.500	590.530	28.500	592.076	43.500	593.947	58.500	593.242	73.500	589.219
13.750	590.503	28.750	592.407	43.750	593.943	58.750	593.126	73.750	589.202
14.000	590.475	29.000	592.750	44.000	593.938	59.000	593.007	74.000	589.186
14.250	590.446	29.250	593.138	44.250	593.934	59.250	592.894	74.250	589.171
14.500	590.413	29.500	593.551	44.500	593.929	59.500	592.784	74.500	589.156
14.750	590.367	29.750	593.952	44.750	593.925	59.750	592.667	74.750	589.142

0 HYDROGRAPH VOLUME= 322645312. CF

PEAK ELEVATION = 595. FEET

FINISH

Chapter 3

MILHY3 : Program details

3.1 Program Contents

MAIN
HONDO
STHYD
CMPHYD
SOILM
HYDCON
TWO
GRAD
SMCURV
PRTHYD
HPLOT
ADHYD
SRC
CMPRC
STT
CMPTT
ROUTE
RESVO
ERROR
SEDT

Functions:
GIT
RMAX
RMIN.

BLOCK DATA.

Chapter 3

3.2 Program Changes Since MILHY2

The main changes made to the MILHY code have been to improve the predictive capability of the downstream conveyance estimation, specifically under out-of-bank conditions. In addition, a modular structure has been established which allows the user to select routines most appropriate to a particular application. The new routines introduced in MILHY3 require the user to select one of four methods of momentum exchange, and a single or multiple routing reach application. The user may also select either the Curve Number routine (reintroduced from the original MILHY code), or the infiltration algorithm utilized in MILHY2.

The structure of the MILHY3 code remains similar to that of MILHY2. The new capabilities are incorporated either in existing subroutines or are facilitated by the user in the 'datal' data set. It is important to note, therefore, that substantial changes must be made to the datal data set before the multiple routing routine can be utilized. The user is strongly recommended to study the example data set given in Chapter 2 of this volume.

Significant program changes have been made in the following subroutines:

CMPRC
ROUTE
PRTHYD

The introduction of the out-of-bank routing facilities and the selection of techniques have increased the amount of data that must be entered from the datal data set. The BLKDTA subroutine has been amended to enable this additional data to be read, and the COMMON BLOCKS have been restructured to improve the efficiency of the transfer of this data. Three COMMON BLOCKS are now utilised; the first contains control and read information, the second

hydrograph information, and the third routing information. Array sizes have been increased in certain variables, notably A, Q and DEEP, and the definition of the variable C has changed. The punch code capabilities have been removed from MILHY3, and several bugs have been fixed.

The version documented in this volume runs on the SUN workstation and many other UNIX environments. Chapter 4 contains the changes necessary to MILHY3, to enable operation on an IBM-PC. These changes are minor except for the provision of a random number generating routine.

3.3 Subroutine Details

SUBROUTINE NAME: MAIN

SYNOPSIS: Opens files for input and output. Initialises certain variables. Calls appropriate subroutine according to command.

COMMAND:

INPUT: Two data files called 'datal' and 'data2' must exist.

'datal' - contains programme controls and data
'data2' - additional information for the infiltration algorithm

See Chapter 2 for details of these two data files

OUTPUT: Opens the output file 'results' to which the details of the simulation are to be sent.

VARIABLES USED:

Variables held in common block 'BLOCKl'

CTBLE(50,11)	command table
ITBLE(50,12)	integer table
ZALPHA (20)	alphanumeric code table
MAXNO	maximum number of data entries for any one command
NCODE	command number
ICC	continuation card
NCOMM	total number of legal commands

Chapter 3

Variables held in common block 'BLOCK2'

OCFS(300,6)	discharge
DATA(310)	data input for each command
RAIN(300)	cumulative precipitation at equal time increments
ROIN(6)	volume of discharge hydrograph
IEND(6)	number of points in hydrograph
DA(6)	drainage area
DT(6)	time increment
PEAK(6)	peak discharge of hydrograph
TIME	simulation start time
KCODE	measurement unit of input data (datal) KCODE = 0 imperial
ICODE	measurement unit of output ICODE = 0 imperial

Variables held in common block 'BLOCK3'

A(20,70)	end area
Q(20,70)	discharge
DEEP(20,70)	elevation of water surface
DP(20)	flow depth for previously computed travel time flow relationship
SCFS(20)	discharge for previously computed travel time flow relationship
C(20,6)	absolute stage elevations
DIST(6)	segment boundary point for each segment of a floodplain and channel cross-section
SEGN(6)	Mannings 'n' for segment of a floodplain and channel cross-section
ISG(6)	last elevation input for each segment
PERQ(20,70)	percentage discharge for segment of a floodplain and channel cross-section
TQ(20,6)	total discharge for cross-section
CC(20)	travel time coefficient for previously computed travel time relationship
LL(6)	number of zero discharge values for segment of a floodplain and channel cross-section
INRC	identification number for upstream segment rating curve
LRC	identification number for downstream segment rating curve

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CONSTRAINTS: The most important constraints in this program involve the limits to array size which are dimensioned in COMMON. For example, program can only hold 6 hydrographs or 6 rating curves at any one time. 15 commands which are defined in BLOCK DATA are used by MILHY2 (as in the original form of MILHY). The legal values for these are provided in HONDO and appendix I.

CALLED BY:

SUBROUTINES CALLED:
HONDO
STHYD
CMPHYD
PRTHYD
HPLOT
ADHYD
SRC
CMPRC
STT
CMPTT
ROUTE
RESVO
ERROR
SEDT

FUNCTIONS CALLED:

NOTES

Chapter 3

SUBROUTINE NAME: HONDO

SYNOPSIS: Reads in command and associated data from file 'datal'
and by comparison to the legal commands contained in CTBLE (initialized in BLOCK DATA), it determines the command number (NCODE). It collects up the variables from the variable format data field.

COMMAND:

INPUT: Data is read in from file 'datal'.
Command must be located in the first 20 columns on each line, and is read in variable ALPHA (11) (FORMAT 2A1,9A2). The data must be in columns 21 to 80, and is read into variable CHAR (60) (FORMAT (60A1).

Legal commands are:

START
STORE HYD
COMPUTE HYD
PRINT HYD
PLOT HYD
ADD HYD
STORE RATING CURVE
COMPUTE RATING CURVE
STORE TRAVEL TIME
COMPUTE TRAVEL TIME
ROUTE
ROUTE RESERVOIR
ERROR ANALYSIS
SEDIMENT YIELD
FINISH

Additional legal entries to file 'datal' include:

'*' in column 1 - if the line is a comment line
'*' in column 80 - if a new page is required for output

OUTPUT: Writes out the command and associated data to file 'results', and returns the value of NCODE to MAIN which is then used to select the next subroutine to be called. All data which has been collected for the command is held in common, in the array DATA (310).

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VARIABLES USED:	Variables held in common plus
	CHAR(60) data and associated text ALPHA(11) command AUXA(10) array used to collect up data AUXB(10) array used to collect up data
CONSTRAINTS:	The form of the data file 'datal' must be strictly adhered to. HONDO will not tolerate spelling mistakes.
	The command and data must also be entered into the correct columns. The data must be in the order which is expected by HONDO (these details are provided in Chapter 2).
CALLED BY:	MAIN
SUBROUTINES CALLED:	
FUNCTIONS CALLED:	GIT

NOTES

Chapter 3

SUBROUTINE NAME; STHYD

SYNOPSIS: A model control procedure. Stores the coordinates of a measured hydrograph and adds a constant baseflow discharge to all data points.

COMMAND:

INPUT: The data input for this command has been read into DATA(310) by HONDO and is transferred from this array into the following variables which are used in this subroutine:

ID
NHD
DT(ID)
DA(ID)
BSF
OCFS(300,ID)

OUTPUT: Stores discharge hydrograph (time and associated discharge values), runoff volume, and peak discharge:

OCFS(300,ID)
ROIN(ID)
PEAK(ID)

VARIABLES USED: Variables held in common plus

ID	storage location number
NHD	hydrograph identification number
BSF	baseflow discharge
DUMMY(300)	discharge values converted to metric units

CONSTRAINTS: Only 6 hydrographs at any one time can be stored by this program. In any one hydrograph, a maximum of 300 points are allowed.

CALLED BY: MAIN

SUBROUTINES CALLED:

FUNCTIONS CALLED:

NOTES: If the addition of baseflow is not required, a zero value must be entered.

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SUBROUTINE NAME: CMPHYD

SYNOPSIS: Hydrological procedure.
Developes unit hydrograph and convolves it with incremental runoff to produce the discharge hydrograph. Runoff is derived by calling subroutine SOILM, utilizing the infiltration, or using the curve number routine

COMMAND: COMPUTE HYD

INPUT: Data has been read into DATA(310) by HONDO and is transferred from this array into the following variables which are used in this subroutine:

ID
NHD
DT(ID)
DA(ID)
CN
HT
XL
RAIN(300)

OUTPUT: Stores the calculated discharge hydrograph, runoff volume, and peak discharge

OCFS(300,ID)
ROIN(ID)
PEAK(ID)

VARIABLES USED: Variables held in common plus
ID storage location number
NHD hydrograph identification number
HT difference in elevation
XL length of main channel

CONSTRAINTS: A maximum of 6 hydrographs can be stored.
A maximum of 300 data can be included in the precipitation data.

CALLED BY: MAIN

SUBROUTINES CALLED: SOILM

FUNCTIONS CALLED:

NOTES: This subroutine has been updated to permit the user to select the curve number routine or the infiltration algorithm. To select the infiltration algorithm, a CN value of zero must be entered.

Chapter 3

SUBROUTINE NAME: SOILM

SYNOPSIS: Simulation of infiltration and hence incremental runoff associated with a particular storm event, and redistribution of soil water after precipitation ceases. Includes a stochastic methodology for incorporating spatial variability of soil hydrological properties.

COMMAND:

INPUT: Certain data has been passed from CMPHYD to SOILM:

DT(ID)
IR
CUMRAIN

Remaining variables are read directly into SOILM from data file 'datal'. The details of the form of this data file and the information which is required by SOILM are elsewhere in this volume.

OUTPUT: Provides incremental runoff which is located in DATA(300) and which is passed back to CMPHYD. This runoff is at the same time interval as the precipitation data which has been supplied (DT(ID)).

VARIABLES USED:

DT(ID)	Time increment for precipitation and hence runoff data
IR	number of rainfall observations
CUMRAIN(251)	cumulative rainfall totals
TIME	time when simulation begins
SIMDUR	simulation duration (hours)
ALR	rain start timem (hours)
AMR	rain stop time (hours)
AF	simulation iteration period (seconds)
NLA	number of cells in layer 1 in soil column
NLS	number of cells in layer 2 in soil column
NLB	number of cells in layer 2 in soil column
NL	number of cells in soil column
TCOM(20)	thickness of each cell (metres)
NSCOL	number of soil columns
IPCAREA	percent are occupied by soil column
SR1	soil water content at saturation, layer 1 in soil column
SR2	soil water content at saturation, layer 2 in soil column
SR3	soil water content at saturation, layer 3 in soil column

ASR1 ASR2 ASR3	Same variable definitions as the three above, but variable types are DOUBLE PRECISION rather than REAL
SSR1	Standard deviation of SR1
SSR2	Standard deviation of SR2
SSR3	Standard deviation of SR3
SATCON	saturated hydraulic conductivity (metres per second) layer 1
SATCON2	saturated hydraulic conductivity (metres per second) layer 2
SATCON3	saturated hydraulic conductivity (metres per second) layer 3
ASATCON ASATCON2 ASATCON3	Same variable definitions as the three above, but variable types are DOUBLE PRECISION rather than REAL
SSATCON1	Standard deviation of SATCON1
SSATCON2	Standard deviation of SATCON2
SSATCON3	Standard deviation of SATCON3
DETCAP	surface detention capacity (metres)
ADETCAP	DOUBLE PRECISION surface detention capacity
SDETCAP	Standard deviation of detention capacity
THETA(20)	initial soil water content for each cell (cubic metres per cubic metres)
ATHETA(20)	DOUBLE PRECISION initial soil water content (cubic metres per cubic metres)
STHETA	Standard deviation of THETA(20)
NQ	number of observations on soil moisture characteristics curve
X(20)	moisture values on soil moisture characteristic curve for layer 1 (cubic metres per cubic metres)
Y(20)	suction values on soil moisture characteristic curve for layer 1 (metres)
X2(20)	moisture values on soil moisture characteristic curve for layer 2 (cubic metres per cubic metres)
Y2(20)	suction values on soil moisture characteristic curve for layer 2 (metres)

X3(20)	moisture values on soil moisture characteristic curve for layer 3 (cubic metres per cubic metres)
Y3(20)	suction values on soil moisture characteristic curve for layer 3 (metres)
AX(20)	Same variable definitions as the
AX2(20)	X(20), X2(20), and X3(20) above, but variable types
AX3(20)	are DOUBLE PRECISION rather than
REAL	
SCURV1	Standard deviation of soil moisture characteristic curve for layer 1
SCURV2	Standard deviation of soil moisture characteristic curve for layer 2
SCURV3	Standard deviation of soil moistire characteristic curve for layer 3
EMAX	maximum evaporation during the day (metres per second)
WT	write-out time interval (hours)

IOUT	determines amount of output
	if (IOUT=1) total output
	if (IOUT=0) shorter output

CONSTRAINTS: A maximum of 10 soil columns for any one subcatchment area is permitted.
The soil moisture characteristic curve can be defined by up to a maximum of 20 points.
The soil column can have a maximum of 20 cells.
The initial soil moisture contents, defined for each cell at the start of simulation, must lie within the range of the soil moisture characteristic curve.

CALLED BY: CMPHYD

SUBROUTINES CALLED:
HYDCON
TWO
GRAD
SMCURV
GO5DDF(NAG subroutine)

FUNCTIONS CALLED:
RMAX
RMIN

<u>NOTES:</u>

Chapter 3

SUBROUTINE NAME:	HYDCON	
SYNOPSIS:	Calculates hydraulic conductivity for a particular layer in the soil column from the soil moisture characteristic curve, using the Millington and Quirk method.	
COMMAND:		
INPUT:	Variables passed from SOILM: X(20) Y(20) SATCON SR	
OUTPUT:	Unsaturated hydraulic conductivity values are passed back to SOILM in Z(20).	
VARIABLES USED:	X(20)	moisture values on soil moisture characteristic curve for the particular layer (cubic metres per cubic metres)
	Y(20)	suction values on soil moisture characteristic curve for the particular layer (metres)
	SATCON	saturated hydraulic conductivity for the particular layer
	SR	saturated soil moisture content for the particular layer
	Z(20)	unsaturated hydraulic conductivity values corresponding to X(20) above.
CONSTRAINTS:	Maximum points on the soil moisture characteristic curve, and hence the hydraulic function is 20.	
CALLED BY:	SOILM	
SUBROUTINES CALLED:		
FUNCTIONS CALLED:		

NOTES

Chapter 3

SUBROUTINE NAME: TWO

SYNOPSIS: Calculates the soil water pressure, hydraulic potential, and hydraulic conductivity for each cell in the soil column, associated with a particular soil water content.

COMMAND:

INPUT: Variables passed from SOILM:

NA
NB
G(20)
GZ(20)
Z(20)
X(20)
Y(20)
DEPTH(20)

OUTPUT: Soil water pressure, hydraulic potential, and hydraulic conductivity are passed back to SOILM

SWP(20)
HPOT(20)
COND(20)

VARIABLES USED:

NA	number of cells in layer 1
NB	number of cells in layer 2
THETA(20)	initial soil moisture content of each cell
G(20)	gradient of soil moisture characteristic curve, ie grad between each pair of points
GZ(20)	gradient of hydraulic function, ie grad between each pair of points
X(20)	moisture values on soil moisture characteristic curve for the particular layer (cubic metres per cubic metres)
Y(20)	suction values on soil moisture characteristic curve for the particular layer (metres) values
Z(20)	unsaturated hydraulic conductivity values corresponding to X(20) above
DEPTH(20)	distance from surface to the midpoint of each cell
SWP(20)	soil water pressure of each cell
HPOT(20)	hydraulic potential of each cell
COND(20)	conductivity of each cell

Chapter 3

CONSTRAINTS: A maximum of 20 cells in the soil column is permitted

CALLED BY: SOILM

SUBROUTINES COMMAND:

FUNCTIONS COMMAND:

NOTES;

Chapter 3

SUBROUTINE NAME:	GRAD	
SYNOPSIS:	Calculates the gradient of the soil moisture characteristic curve, and hydraulic conductivity function.	
INPUT:	Variables passed from SOILM: X(20) Y(20) Z(20)	
OUTPUT:	Variables containing gradients passed back to SOILM. G(20) GZ(20)	
VARIABLES USED:	X(20)	moisture values on soil moisture characteristic curve for the particular layer (cubic metres per cubic metres)
	Y(20)	suction values on soil moisture characteristic curve for the particular layer (metres) values
	Z(20)	unsaturated hydraulic conductivity values corresponding to X(20) above
	G(20)	gradient of soil moisture characteristic curve, i.e. gradient between each pair of points
	GZ(20)	gradient of hydraulic function, i.e. gradient between each pair of points
CONSTRAINTS:	A maximum of 20 cells in the soil column is permitted	
CALLED BY:	SOILM	
SUBROUTINES COMMAND:		
FUNCTIONS COMMAND:		

<u>NOTES</u>

Chapter 3

SUBROUTINE NAME: SMCURV

SYNOPSIS: Generates new soil moisture characteristic curve based
on the randomly generated moisture values.

INPUT: Variables passed from SOILM:

AX(20)
Y(20)
SCURV
SR
NQ

OUTPUT: Coordinates of new soil moisture characteristic curve passed back to SOILM:

XNEW(20)
YNEW(20)

VARIABLES USED:

AX(20)	values of soil moisture on input soil moisture characteristic curve DOUBLE PRECISION variable type
Y(20)	values of suction on input soil moisture characteristic curve
SCURV	standard deviation of soil moisture characteristic curve in DOUBLE PRECISION
SR	saturated soil moisture content
NQ	number of coordinates defining soil moisture characteristic curve
XNEW(20)	generated soil moisture content on new soil moisture characteristic curve
YNEW(20)	generated suction values on new soil moisture characteristic curve

CONSTRAINTS: A maximum of 20 points to define the soil moisture characteristic curve

CALLED BY: SOILM

SUBROUTINES CALLED: G05DDF (NAG subroutine)

FUNCTIONS CALLED: RMIN
RMAX

NOTES

Chapter 3

SUBROUTINE NAME; PRTHYD

SYNOPSIS: Model control procedure.
Prints out the coordinates of a hydrograph and/or the peak value and runoff volume.
Converts OCFS(300,ID) to a stage array, S(300,ID) using a recalled rating curve.

COMMAND: PRINT HYD.

INPUT: The data input for this command has been read into OCFS(300,ID) by HONDO and is transferred from this array into the following variables which are used in this subroutine:

ID
NPK
IDR
IN

Details of the hydrograph are held in common and are referenced by ID.

OUTPUT: Discharge, DUMMY(300) or stage, S(300,ID) hydrograph are written to output file 'results'.

DUMMY(300)
S(300,ID)
ROIN1
PEAK1
PEAKS

VARIABLES USED: Variables in common plus

ID	storage location number
NPK	form of output required 0 peak and volume only 1 discharge hydrograph 2 stage hydrograph
IDR	identification number of rating curve or segment to be used for conversion to a stage hydrograph
IN	format of output 0 five columns across page 1 single column
DUMMY(300)	discharge array (converted to metric units if required)
S(300,ID)	stage array (converted to metric units if required)
PEAK1	peak discharge
ROIN1	volume of hydrograph
PEAKS	peak stage

Chapter 3

CONSTRAINTS: Maximum of 300 points define the hydrograph. For conversion to stage hydrograph, rating curve must have been computed. A stage hydrograph cannot be computed if multiple routing is invoked.

CALLED BY: MAIN

SUBROUTINES CALLED:

FUNCTIONS CALLED:

NOTES: Conversion to a stage hydrograph uses a previously computed rating curve.

Chapter 3

SUBROUTINE NAME: HPLOT

SYNOPSIS: Model control procedure.
Plots either 1 or 2 hydrographs on a set of axis.

COMMAND: PLOT HYD.

INPUT: The data input for this command has been read into DATA(310) by HONDO and is transferred from this array into the following variables which are used in this subroutine:-

ID1
ID2

Details of the 2 hydrographs are held in common variables and are references by ID1 and ID2

OUTPUT: Discharge plots and axis are written to output file 'results'.

CFS(300)

VARIABLES USED: Variables in common plus

ID1
ID2

CONSTRAINTS: If the time interval of the two hydrographs to be plotted is not equal, the larger increment is selected and the other hydrograph points are interpolated at this increment.

CALLED BY: MAIN

SUBROUTINES CALLED:

FUNCTIONS CALLED:

NOTES:

Chapter 3

SUBROUTINE NAME: ADHYD

SYNOPSIS: Model control procedure
Adds together the coordinates of two hydrographs

COMMAND: ADD HYD

INPUT: The data input for this command has been read into DATA(310) by HONDO and is transferred from this array into the following variables which are used in this subroutine:

ID
NHD
ID1
ID2

Details of the 2 hydrographs are held in common variables and are referenced by ID1 and ID2

OUTPUT: The discharge coordinates, peak discharge, and runoff volume of the resultant hydrograph:

OCFS(300,ID)
PEAK(ID)
ROIN(ID)

VARIABLES USED: Variables in common plus

ID	storage location number for resultant hydrograph
NHD	hydrograph identification number of resultant hydrograph
ID1, ID2	storage location numbers of the two hydrographs to be added

CONSTRAINTS: If the time interval of the two hydrographs to be added is not equal, then the smaller increment is selected and the other hydrograph points are interpolated at this increment.

CALLED BY: MAIN

SUBROUTINES CALLED:

FUNCTIONS CALLED:

NOTES;

Chapter 3

SUBROUTINE NAME: SRC

SYNOPSIS: A model control procedure
Stores a rating curve in form of elevation, end area, discharge table

COMMAND: STORE RATING CURVE

INPUT: The data input for this command has been read into DATA(310) by HONDO and is transferred from this array into the following variables which are used in this subroutine:

ID
VS
DEEP(20,ID)
A(20,ID)
Q(20,ID)

OUTPUT: Stores the rating curve in variables held in common:

DEEP(20,ID)
A(20,ID)
Q(20,ID)

VARIABLES USED: Variables held in common plus

ID	storage location number of rating curve
VS	valley cross section number

CONSTRAINTS: Only 6 rating curves can be held within the program at any one time.
Maximum number of points defining rating curve are 20.

CALLED BY: MAIN

SUBROUTINES CALLED:

FUNCTIONS CALLED:

NOTES:

Chapter 3

SUBROUTINE NAME: CMPRC

SYNOPSIS: A hydrological procedure.
Computes rating curve for valley cross section using Mannings equation. If turbulent exchange routines are invoked calculates rating curve incorporating momentum transfer between channel and floodplain flows during out-of-bank conditions. If multiple routing reaches are invoked calculates separate rating curves for each segment of the cross-section and computes the percentage of total flow which would occur in each segment at the twenty stage computation points.

COMMAND: COMPUTE RATING CURVE

INPUT: The data input for this comm… has been read into DATA(310) by HONDO and is transferred from this array into the following variables which are used in this subroutine:

ID
IT
MR
VS
NSEG
ELO
EMAX
SLOPE1
SLOPE2
SEGN(NSEG)
DIST(NSEG)
DATA(10:310)

OUTPUT: Stores the rating curve and percentage flow in each segment in variables held in common

A(20,ID)
Q(20,ID)
C(20,ID)
DEEP(20,ID)
PERQ(20,ID)
TQ(20,ID)

VARIABLES USED: Variables held in common plus

ID	storage location number for rating curve
IT	turbulent exchange between main channel and floodplains invoked
MR	multiply routing reaches invoked

VS	valley section identification number
NSEG	number of segments in valley section
ELO	lowest elevation
EMAX	maximum elevation
SLOPE1	channel slope
SLOPE2	flood plain slope
DATA (10:310)	alternate distances and elevations (defining cross section)

CONSTRAINTS: Maximum number of segments in a cross section is 6. Maximum number of points in a rating curve is 20. Turbulent exchange and multiple routing reaches may be invoked independently but for either to operate there must be a floodplain segment on either side of channel segments. For accuracy the user is recommended to have cross-sectional positional data (DIST and ELEV) close to segment boundaries. If momentum exchange is not or cannot be invoked, the MILHY2 version using IT = 2 is used.

CALLED BY: MAIN

SUBROUTINES CALLED:

FUNCTIONS CALLED:

NOTES: The user is recommended to study the example datal data set in Chapter 2 of this volume before undertaking multiple routing applications.

Chapter 3

SUBROUTINE NAME:	STT
SYNOPSIS:	Model control procedure. Stores a depth, flow, travel time table (used in flood routing).
COMMAND:	STORE TRAVEL TIME
INPUT:	The data input for this command has been read into DATA(310) by HONDO and is transferred from this array into the following variables which are used in this subroutine: ID REACH XL SLOPE MET1 DP(20) SCFS(20) CC(20)
OUTPUT:	Stores travel time table in following common variables: DP(20) SCFS(20) CC(20)
VARIABLES USED:	Variables held in common plus ID storage location number REACH reach identification number XL length of reach SLOPE slope of reach
CONSTRAINTS:	A maximum of 20 points are allowed to define a travel time table.
CALLED BY:	MAIN
SUBROUTINES CALLED:	
FUNCTIONS CALLED:	

NOTES:

Chapter 3

SUBROUTINE NAME:	CMPTT
SYNOPSIS:	Hydrological procedure. Compute travel time table.
COMMAND:	COMPUTE TRAVEL TIME
INPUT:	Data has been read into DATA(310) by HONDO and is transferred from this array into the following variables which are used in this subroutine: ID REACH NOVS XL SLOPE MR INRC LRC.
OUTPUT:	Stores the travel time table in following common variables: DP(20) SCFS(20) CC(20)
VARIABLES USED:	Variables held in common plus

ID	storage location number
REACH	reach identification number
NOVS	number of valley sections in the reach
XL	length of reach
SLOPE	Slope of reach
MR	multiple routing invoked
INRC	upstream segment rating curve identification number
LRC	downstream segment rating curve identification number

CONSTRAINTS:	A maximum of 20 points are allowed to define a travel time table. A maximum of 6 valley sections are permitted in a reach, except where multiple routing reaches are invoked where <u>two</u> segment section must be identified.
CALLED BY:	MAIN

Chapter 3

SUBROUTINES
CALLED:

FUNCTIONS
CALLED:

NOTES: If multiple routing reaches are invoked, a compute travel time table and route command must be entered for each segment routing reach (see Chapter 2 of this volume).

Chapter 3

SUBROUTINE NAME: ROUTE

SYNOPSIS:

A hydrological procedure.
Routes a hydrograph through a reach using the variable storage coefficient method.
If multiple routing reaches are invoked, routes a hydrograph through a segment routing reach.
Also calculates inflow hydrograph for segment reach using PERQ(20) from rating curve.

COMMAND: ROUTE

INPUT:

The data input for this command has been read into DATA(310) by HONDO and is transferred from this array into the following variables which are used in this subroutine:

ID
NHD
IDH
DT(ID)
MR

Details of the hydrograph to be routed are held in common variables and are references by IDH.
Details of the inflow segments rating curve are held in common variables and are referenced by:

PERQ(20)
TQ(20)
C(20,INRC)
INRC.

OUTPUT:

Stores the calculated outflow hydrograph, its peak discharge, and runoff volume in common variables:

OCFS(300,ID)
PEAK(ID)
ROIN(ID)

Proportional discharge for each time increment value (if multiple routing reaches are invoked) written to output file 'results'.

DOCF(300,ID)

VARIABLES USED:

Variables held in common plus

ID	storage location number of calculated outflow hydrograph
NHD	hydrograph identification number of outflow hydrograph

IDH	storage location number of inflow hydrograph
DT(ID)	iteration period of outflow hydrograph
MR	multiple routing invoked
DOCFS	dummy discharge area to prevent overwriting of inflow array
P	percentage of inflow in multiple routing reach segment

CONSTRAINTS: Discharges included in the inflow hydrograph must be within the limits of the travel time table, otherwise there is no way to define the travel time coefficient. If the solution to the routing equations fails to converge after 10 iterations, convergence is forced.
If multiple routing reaches are invoked the inflow hydrograph must not exceed the rating curve used to compute proportional inflow in segment.

CALLED BY: MAIN

SUBROUTINES CALLED:

FUNCTIONS CALLED:

<u>NOTES:</u> If multiple routing reaches are invoked, a compute travel time table and route command must be entered for each segment routing reach. Also t.e identification number of the inflow and outflow hydrographs must not be the same (see Chapter 2 of this volume).

Chapter 3

SUBROUTINE NAME:	RESVO
SYNOPSIS:	A hydrological procedure. Routes hydrograph through a reservoir.
COMMAND:	ROUTE RESERVOIR
INPUT:	The data input for this command has been read into DATA(310) by HONDO and is transferred from this array into the following variables which are used in this subroutine: ID NHD IDH SCFS(20) STORE Details of the inflow hydrograph are held in common vriables and are referenced by ID: DT(ID) DA(ID)
OUTPUT:	The calculated outflow hydrograph, peak discharge, and runoff volume is stored in common variables: OCFS(300,ID) PEAK(ID) ROIN(ID)
VARIABLES USED:	Variables held in common plus

ID	storage location number of calculated outflow hydrograph
NHD	hydrograph identification number of outflow hydrograph
IDH	storage location number of inflow hydrograph
SCFS(20)	discharge values of the storage discharge relationship defined for the reservoir
STORE	storage values of the storage discharge relationship defined from the reservoir

CONSTRAINTS: The discharge of the inflow hydrograph must be within the storage discharge relationship defined from the reservoir. A maximum of 20 points are allowed to define this relationhip.

Chapter 3

CALLED BY: MAIN

SUBROUTINES
CALLED:

FUNCTIONS
CALLED:

NOTES:

Chapter 3

SUBROUTINE NAME: ERROR

SYNOPSIS: Model control procedure.
Calculates a number of indices or objective functions which detail the degree of fit between two hydrographs.

COMMAND: ERROR

INPUT: The data input for this command has been read into DATA(310) by HONDO and is transferred from this array into the following variables which are used in this subroutine:

ID1
ID2

Details of the 2 hydrographs are held in common variables and are referenced by ID1 and ID2

OUTPUT: The values of MILHY's original error statistics plus an additional 13 objective functions are written to output file 'results'.

ESDEV
PCTER
OF1
OF2
OF3
OF4
OF5
OF6
OF7
OF8
OF9
OF10
OF11

VARIABLES USED: Variables in common plus

ID1	storage location number of first hydrograph (usually assumed to be measured)
ID2	storage location number of second hydrograph (usually assumed to be calculated)
ERR	error (measured - calculated discharge)
ESDEV	error standard deviation
PCTER	percentage peak discharge error

OF1	absolute sum of errors
OF2	ordinary least squares
OF3	log of ordinary least squares
OF4	relative sum of errors
OF5	absolute error difference
OF6	relative error difference
OF7	absolute error divided by variance
OF8	relative error divided by variance
OF9	absolute error difference divided by variance
OF10	relative error difference divided by variance
OF11	Pearsons correlation coefficient

CONSTRAINTS: The first hydrograph (ID1) is taken to be the measured. All indices are printed out in file 'results' in metric units.

CALLED BY: MAIN

SUBROUTINES CALLED:

FUNCTIONS CALLED:

NOTES:

Chapter 3

SUBROUTINE NAME: SEDT

SYNOPSIS: A hydrological procedure.
Computes sediment yield for a field using the Universal soil loss equation.

COMMAND: SEDIMENT YIELD

INPUT: The data input for this command has been read into DATA(310) by HONDO and is transferred from this array into the following variables which are used in this subroutine:

ID
SOIL
CROP
CP
SL

Details of the hydrograph are held in common variables and are referenced by ID:

ROIN(ID)
DA(ID)
PEAK(ID)

OUTPUT: Writes out the sediment yield to the output file 'results':

SED

VARIABLES USED: Variables held in common plus

ID	storage location number of hydrographs
SOIL	soil erodibility factor
CROP	the cropping management factor
CP	The erosion control practice factor
SL	the slope length and gradient factor

CONSTRAINTS:

CALLED BY: MAIN

SUBROUTINES CALLED:

FUNCTIONS CALLED:

NOTES:

Chapter 3

FUNCTION NAME:	GIT (TCARD, J, JLAST, SHIFT).	
SYNOPSIS:	Converts alphabetic array to floating point number.	
INPUT:	TCARD(10) J JLAST SHIFT A(10)	 CONVERTS TO NUMBERS
OUTPUT:	GIT	
VARIABLES USED:	TCARD J JLAST SHIFT A(10)	
CONSTRAINTS:		
CALLED BY:	HONDO	

Chapter 3

FUNCTION NAME: RMAX(X,NQ)

SYNOPSIS: Returns the maximum element in a REAL array.

INPUT: X(NQ) X is a REAL array of size NQ

OUTPUT: RMAX

VARIABLES USED: X(NQ)
RMAX

CONSTRAINTS:

CALLED BY: SOILM

FUNCTION NAME: RMIN(X,NQ)

SYNOPSIS: Returns the minimum element in a REAL array.

INPUT: X(NQ) X is a REAL array of size NQ

OUTPUT: RMAX

VARIABLES USED: X(NQ)
RMAX

CONSTRAINTS:

CALLED BY: SOILM

NOTES:

Chapter 3

SUBROUTINE NAME: BLOCK DATA

SYNOPSIS: Initializes certain variables. These variables are used to determine the number of commands, the command, the command number, the maximum number of data entries which are associated with the command, and the data which is entered in the variable format data entry area.

INPUT:

OUTPUT: Initialized arrays:

ZALFA(20)
CTBLE(50,11)
ITBLE(50,2)
NCOMM

VARIABLES USED:

ZALFA(20) alphanumeric code table containing:

1234567890 *.,-(filled with blanks)

CTBLE(50,11) command table containing:

START (filled with blanks)
STORE HYD
COMPUTE HYD
PRINT HYD
PLOT HYD
ADD HYD
STORE RATING CURVE
COMPUTE RATING CURVE
STORE TRAVEL TIME
COMPUTE TRAVEL TIME
ROUTE
ROUTE RESERVOIR
ERROR ANALYSIS
SEDIMENT YIELD
FINISH
(filled with blanks)

ITBLE(50,2) integer table containing:

1	4
2	305
3	310
4	4
5	2
6	4
7	62
8	310

Chapter 3

9	45
10	8
11	5
12	4
13	2
14	5
15	0

NCOMM number of commands contains: 15

CONSTRAINTS:

CALLED BY:

SUBROUTINES CALLED:

FUNCTIONS CALLED:

NOTES:

Chapter 3

3.4 Infiltration Algorithm

The basic structure of the computer implementation of the infiltration model is illustrated in figure 3.1. It has been written in Fortran 77 so as to be compatible with MILHY.

This document provides more details of the subroutines SOILM, HYDCON, TWO, GRAD, and SMCURV, which are included in the listing of MILHY3. Together these subroutines comprise the code for the physically based infiltration model.

Substantial comments exist within the computer code.

The subroutine SOILM is divided into three parts, an initial, dynamic, and terminal section. Each of these will be discussed in turn. However, primarily, three series of operations are undertaken:

1. SOILM comprises firstly, a series of declaration statements including DIMENSION and variable type statements.

2. The first four lines of the data file 'data2' (unit number 25) are then read into the program. These lines include the variables which control the soil moisture simulation, such as the simulation start time (TIME), storm start time (ALR), storm stop time (AMR), simulation duration (SIMDUR), a variable which indicates the amount of output required (IOUT), simulation iteration time (AF), write-out interval (WT), and the number of soil columns in the particular subcatchment (NSCOLS).

3. The real array CUMRAIN(251) which has been passed from CMPHYD is then transformed from cumulative precipitation totals (in inches) at equal time intervals (DT), into precipitation totals (in mm) for each time increment:

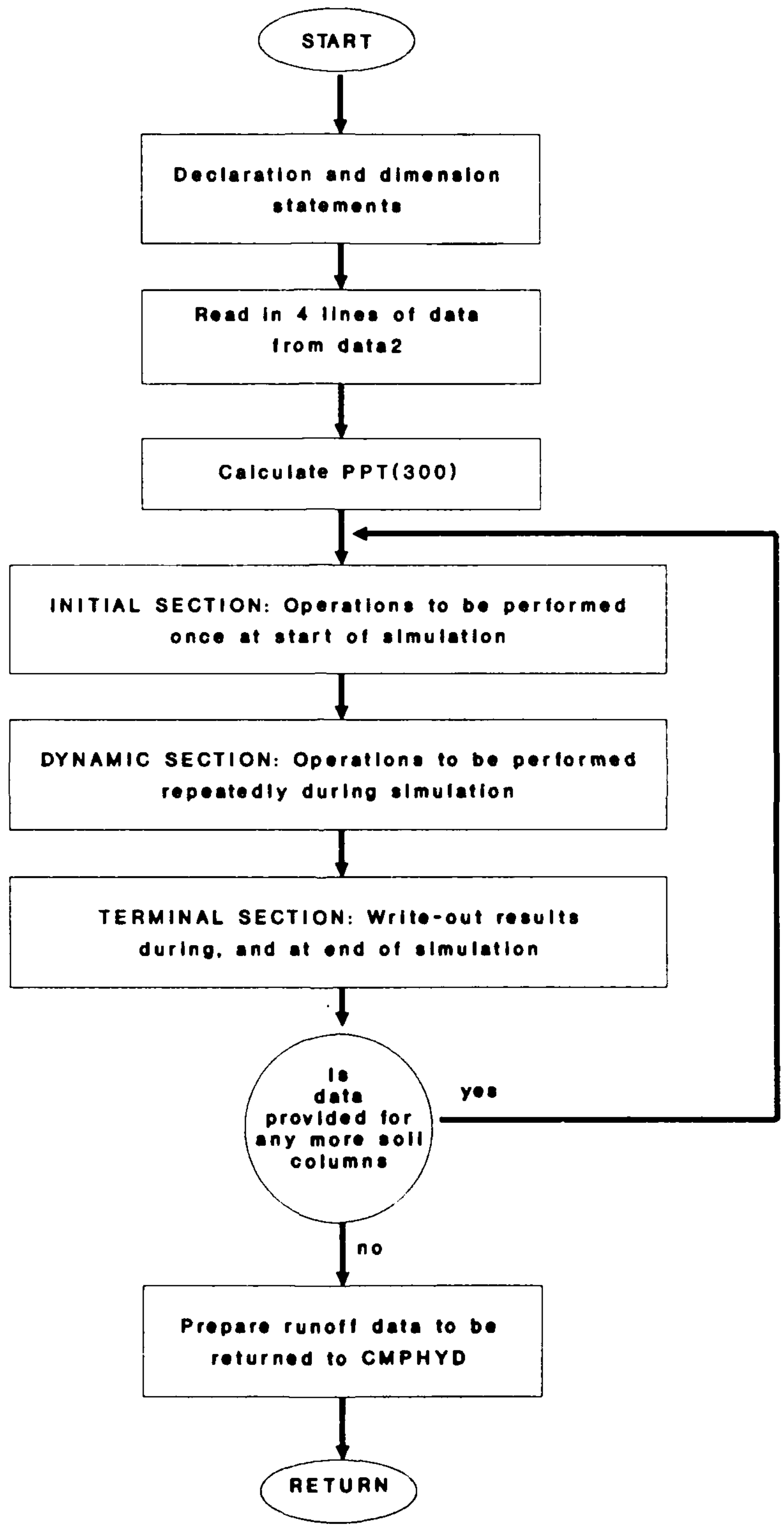

Figure 3.1
Structure of SOILM Subroutine

```
      IRR=IR+1
      DO 100 I=1,IRR
100   PPT(I)=(CUMRAIN(I+1)-CUMRAIN(I))*0.0254
```

3.4.1 Initial section

1 Read in data.

The data relating to a single soil column are read into the program. All of the details to operate the stochastic version of the model are also read in at this stage. If the deterministic version of the infiltration model is required, then enter all standard deviations as zero.

2 If the storm start and stop have been entered as 12 hour clock rather than 24 hour clock, it is possible that the storm may start before it stops; the following calculation prevents this. Assume that times entered in 'data2' are correct:

```
      IF(AMR.LT.ALR)THEN
         AMR=AMR+24
      ENDIF
```

3 Check data inputs.

A series of checks are performed on the data which has just been read in. When an error occurs, the value of NERROR is increased by one and the checks continue. At the end of this section of the code, if NERROR exceeds 0, then the program stops. This allows all of the data for the soil column to be checked during one run of the program.

Details of the checks which are performed are well documented in the code.

Chapter 3

4. DEPTH calculation.

DEPTH	the distance from the ground level to the midpoint of each cell in the soil column.
DIST	the distance between the midpoints of any two adjacent cells
TCOM(20)	thickness of each cell (input in 'data2')

5. Parameter variability calculations

The five input variables:

DETCAP	*detention capacity*
THETA(20)	soil moisture content of each cell
SR	saturated soil moisture content of each layer
SATCON	saturated hydraulic conductivity of each layer
X(20)	moisture content of each point on the soil moisture characteristic curve

are all varied stochastically. The NAG function GO5DDF is called which returns a randomly selected variable from a normal distribution according to a given mean and standard deviation.

This section of the code generates one set of randomly distributed variables and the simulation continues using these values. To represent variability in the hydrograph response, however, this random selection and the use of these generated values must be repeated many times.

A series of checks are performed on randomly generated values to ensure physical realism.

Chapter 3

DETCAP

DETCAP=G05DDF(ADETCAP,SDETCAP)	Call NAG routine. ADETCAP is a DOUBLE PRECISION mean value of detention capacity. Therefore, DETCAP is the randomly generated value of detention capacity which will be used in this simulation.
IF(DETCAP.LT.0.)DETCAP=0	If the randomly generated value is less than zero, then set it to zero, as zero is a physically impossible value for this variable
SD=SDETCAP WRITE(6,1180)SD 1180 FORMAT ('.....	The details are written out to the output file 'results'.

SR

The procedure for this variable is as for DETCAP.

X(20)

The generation of the stochastic soil moisture curve is achieved by calling subroutine SMCURV. In this subroutine, firstly, arrays are dimensioned, and variables declared.

X(1)=G05DDF(AX(1),SCURV)	The first moisture value on the curve (the driest point) is first used to generate its random value.

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`IF(X(1).LT.O.)X(1)=0.001`	Random value prevented from being zero or negative.

`DO 100 I=2,NQ`
`X(I) = G05DDF(AX(I),SCURV)`
`100 IF(X(I).LE.X(I-1))`
`X(I)=X(I-1)+0.001`
	For the remaining moisture values, generate random values The soil moisture curve is prevented from assuming a reverse gradient

`IF(X(NQ).GE.SR)SR=X(NQ)+0.001`	The wettest point of the soil moisture curve is prevented from assuming a value greater than the saturated soil moisture content determined for that layer

The gradients (G(20)) of this new soil moisture characteristic curve are then calculated.

The maximum and minimum moisture values of the curve are then calculated by referencing the functions RMAX and RMIN. The size of equal intervals in the moisture values are thus determined.

The new values of moisture and suction (at equal moisture intervals) are then evaluated XNEW(20) and YNEW(20). These are passed back to SOILM, where they are read into arrays X(20) and Y(20).

This procedure is repeated for each soil moisture characteristic curve (maximum 3).

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SATCON

The procedure for generating random values for SATCON is similar to DETCAP, except that the DOUBLE PRECISION mean values for SATCON and logged as SATCOM, are assumed to have a log-normal distribution.

THETA(20)

The procedure for generating random values for initial moisture is the same as for DETCAP. More checks on the randomly generated values are performed.

For the cells in each layer

1 - NLA	in layer 1	
NLAA - NLH	in layer 2	(NLAA=NLA+1)
NLBB - NL	in layer 3	(NLBB=NLH+1)

The initial moisture content is not permitted to exceed those moisture values in the soil moisture characteristic curve.

6. The unsaturated hydraulic conductivity function is derived from the soil moisture characteristic curve using the Millington and Quirk equation. This calculation is carried out in subroutine HYDCON, which is called for each soil layer. HYDCON is a straight translation of the Millington and Quirk equation.

7. The initial conditions are written out to data file 'results'. The following information is displayed:

   (a) The moisture, suction and unsaturated hydraulic conductivity values.

   (b) The start conditions TIME, ALR, AMR, DT, AF, EMAX, DETCAP

The initial relative saturation for each cell is calculated as the initial moisture content divided by the saturated soil moisture content for the layer.

(c) The initial soil conditions for each cell in the soil column.

8. Certain variables are initialised:

WDATA(300,10)	a real array which contains the runoff produced by each soil column (up to 10 is permitted) and which is weighted by the percentage area which the soil type occupies in the subcatchment
WATI	initial water content of soil column - a variable used in the water balance check
ANFLUX(20)	net flux of soil water between two adjacent cells
CTIME	current time in seconds
SRAINI	variable used to calculate rainfall excess
CUMDRN	cumulative drainage out of the bottom cell in the soil column
CINFIL	cumulative infiltration
SUMD	rainfall excess
ICOUNT	integer count
EVAPI	cumulative evaporation
SOG	relative saturation of cell 1
RTOT	runoff total
ANFILT	infiltration into cell 1
PPTT	cumulative precipitation
TG	the length of time (in seconds) since the simulation began

9. A calculation is performed to determine the initial soil moisture content of the soil column (WATI). This is used as a check on the numerical stability of the solution of the Richards equation.

10. The gradients of the soil moisture characteristic curve (G(20)) and the hydraulic conductivity function (GZ(20)) are calculated by calling subroutine GRAD. This subroutine is called for each layer in turn.

3.4.2 Dynamic section

This comprises a series of operations located in loop number 9995, which are performed repeatedly at each time step. This time interval is specified in 'data2' by the value of variable AF.

1 ITMAX the number of iterations which are required (SIMDUR is input in hours and therefore must be converted to seconds. AF is in seconds).

2 Loop number 9995 is the major loop in this simulation. An internal clock is set and updated as the simulation proceeds.

3 Calculate water volume of each cell

Loop number 300 determines the volume of each cell by multiplying soil moisture content by cell thickness.

For each cell, the moisture content is known from the initial conditions provided by the user, or from the calculations performed in the previous time interval.

Chapter 3

4 24-hour clock

The real time for the current iteration period is calculated. CTIME was initialised in the initial section, in point number 8 above.

5 Calculation of soil water pressure, conductivity, and hydraulic potential for each cell.

These variables are calculated by calling subroutine TWO. This subroutine is called three times, once for each layer in the soil column:

1 - NLA	cells in layer 1
NLAA - NLH	cells in layer 2
NLBB - NL	cells in layer 3

Firstly, the soil water pressure (SWP(20)) which corresponds to the moisture content (THETA(20)) of each cell is derived from a linear interpolation procedure from the known points on the moisture characteristic relation.

Secondly, unsaturated hydraulic conductivity (COND(20)) is derived by similar means from the hydraulic conductivity function.

Thirdly, the hydraulic potential of each cell (HPOT(20)) is given by the following equation:

HPOT(I) = SWP(I) - DEPTH(I)

where DEPTH(I) represents the depth from the surface to the midpoint of each cell.

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6. Determine rainfall

Rainfall for the current time step is derived from the rainfall data input.

```
T1=T*AF/3600.0          T1 is the time in hours when the current
                        iteration period ends

IF(T1.LE.(ALR-TIME).OR.T1.GT.(AMR-TIME))THEN
                        A check that the end of the current
                        iteration period occurs during the storm
                        period.  Note that the simulation start
                        (TIME) may be defined as some period of
                        time before the storm starts (ALR and
                        that the simulation duration (SIMDUR)
                        may be longer than the storm period
                        (AMR-ALR).

     SRAIN=0.0.         If T1 is outside storm period then there
                        is obviously no rain.

ELSE
                        If T1 is within storm period,

     T2=T1(AF/3600.0)
     IELEM=((T2-(ALR-TIME))/DT)+1  IELEM  the element in the
                                          array PPT which
                                          corresponds to T1

     SRAIN=PPT(IELEM)/)DT*3600.0)  SRAIN  the precipitation
                                          (per second) which
                                          occurs in this
                                          iteration period

ENDIF
```

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PPTT=PPTT+(SRAIN*AF) PPTT cumulative precipitation (initialised in initial section, point 8 above)

7 Average conductivity of each cell

The average conductivity determines the rate of flow between adjacent cells. Loop number 210 determines this property (AVCOND(I), where I=2,NL. AVCOND(I) is given by the following relation

```
AVCOND(I)=(COND)I-1)*TCOM(I-1)+COND(I)*TCOM(I))/
          (TCOM(I-1)+TOM(I))
```

where:

COND(I) hydraulic conductivity of each cell
TCOM(I) thickness of each cell

8 Bottom boundary condition

The flux out of the bottom cell (FLUX(NLL)) is assumed to be equal to the hydraulic conductivity of that cell (COND(NL)), although other bottom boundary conditions could be specified.

Note: NLL=NL+1 initialised after the READ statements near to the beginning of this subroutine.

9 Flux between cells

The flux into each cell, except for the surface cell, is given by Darcy's law, which in discrete form and for the flux from cell (I-1) into cell (I) becomes:

```
FLUX(I)=(HPOT(I-1)-HPOT(I))*AVCOND(I)/DIST(I)
```

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10 Top boundary condition

The determination of the flux into the top cell is crucial for this application.

For each iteration period, the following variables are calculated:

BNCAP	infiltration capacity
SUMD	precipitation excess
DETAIN	the amount detailed on the surface
EVAP	evaporation rate
ANFILT	infiltration rate into cell 1
RUNOFF	runoff in the iteration period
RTOT	cumulative runoff total

The structure of this section of SOILM is illustrated in figure 3.2.

Firstly, the infiltration capacity is calculated. This depends on the characteristics of cell 1. BNCAP is the Darcian flux into the middle of the first cell from a saturated soil surface at which the pressure potential is assigned a value of zero:

```
BNCAP=(0.0-HPOT(1))*0.5*(SATCON+COND(1))/DIST(1)
```

Secondly, the precipitation excess (SUMD) is then calculated and cumulated throughout the simulation duration.

If SUMD is positive, it represents excess water which is detained on the surface (DETAIN).

The next section considers rainfall:

If it is raining: Evaporation (EVAP) is set to zero.

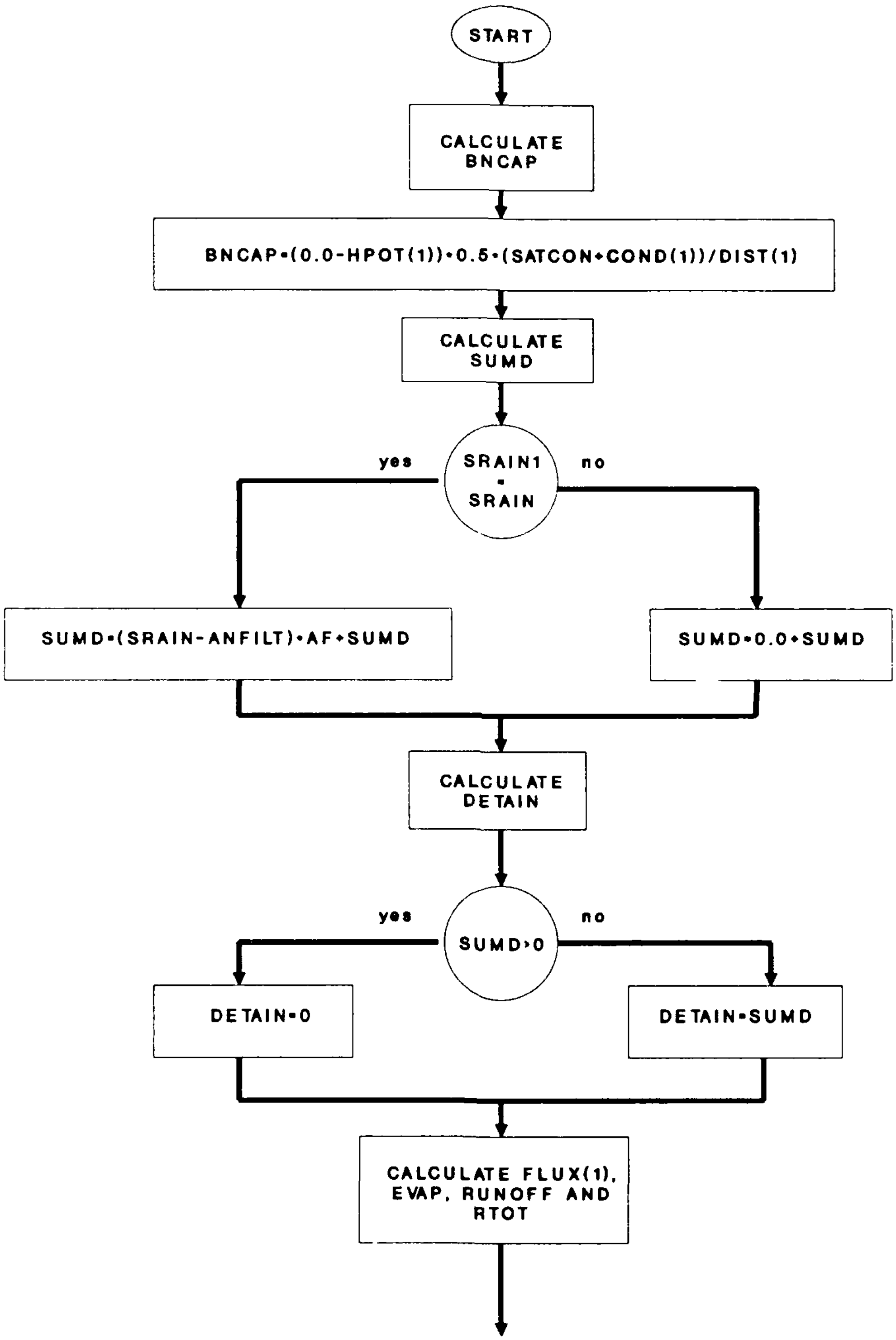

Figure 3.2
Determination of Top Boundary Conditions

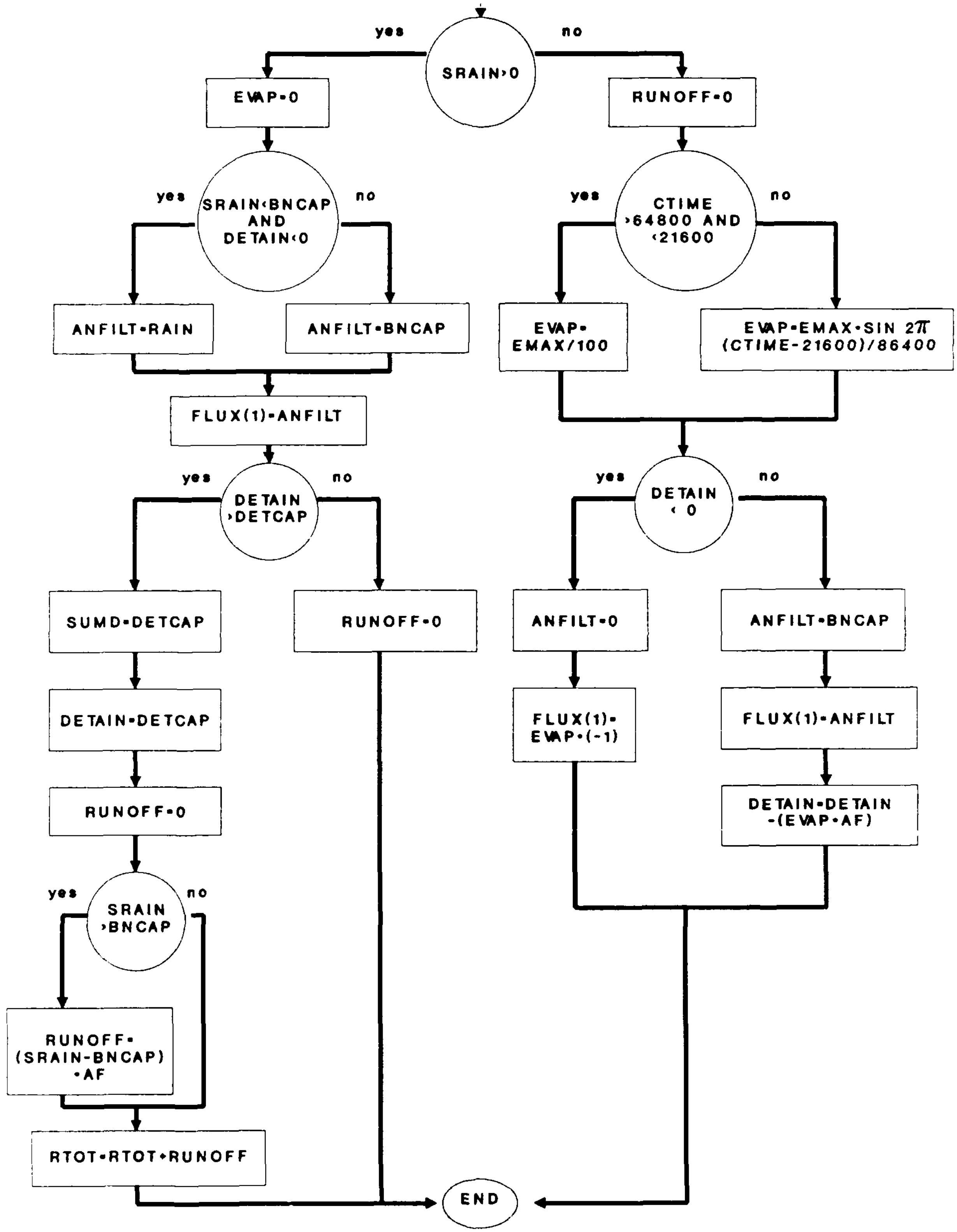

Figure 3.2 (cont.)
Determination of Top Boundary Conditions

Provided that the rainfall rate for the current iteration period (SRAIN) is smaller than the infiltration capacity (BNCAP), and there is no surface detention (DETAIN=0), the flux into cell 1 (ANFILT) equals the rainfall rate (SRAIN). If these conditions are not met, then the flux (ANFILT) equals the infiltration capacity (BNCAP).

If there is surface detention (DETAIN), and this exceeds the detention capacity (DETCAP), and the rainfall rate (SRAIN) exceeds the infiltration capacity (BNCAP) then runoff occurs (RUNOFF).

If it is not raining: Runoff is set to zero.

The evaporation rate (EVAP) is derived from a simple isothermal relation

If there is no water detailed on the surface (DETAIN), then water may move out of cell 1 at a rate equal to the evaporation rate. If there is water remaining on the surface from the storm, water moves into cell 1 at a rate equal to the infiltration capacity. The evaporation and infiltration which occurred during the iteration period are then deducted from the surface detention (DETAIN).

11 Changes in soil moisture content

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When the fluxes (FLUX(20)) have been determined, the moisture content of each cell is recalculated in consideration of these fluxes. The net change in the moisture content of each cell is given by ANFLUX(20)):

ANFLUX(I)=FLUX(I)-FLUX(I+1)

The new moisture content is thus given as:

THETA(I)=(VOL(I)+ANFLUX(I))/TCOM(I)

During recalculation of new moisture contents, it is possible that the newly calculated THETA(20) may exceed the saturated soil moisture content for the cell, therefore a series of checks are performed to ensure that THETA(20) does not exceed SR, and that the associated soil water pressure SWP(20) is also set to zero (saturation).

12 Cumulative totals.

Updates are then provided for:

CUMDRN	cumulative drainage
EVAPI	cumulative evaporation
CINFIL	cumulative infiltration
SOG	relative saturation of cell 1

3.4.3 Terminal section

In this section, a write out of current conditions of each cell in the soil column, the precipitation, and any surface storage, runoff or evaporation which may have occurred is performed.

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1 The program checks the time on its internal clock against the time interval for which a printed copy of the soil column conditions is required (this will normally equal the time interval of rainfall data). If the two do not agree, the program moves to statement number 9995, and returns to the beginning of the dynamic section. If they do agree, then the program proceeds to the terminal section.

2 T the current time. This is written out to file unit number 6, 'results'.

3 If IOUT (defined in 'data2') is zero, then only a limited amount of written output data is required, and the program moves to statement number 305 where the water balance calculation is undertaken and details written to 'results'. If IOUT does not equal 0, then the full details are required.

4 Write-out conditions of the soil column.

The conditions of each cell in the soil column are written out at time T.

5 Water balance check.
The water content of the soil column is recalculated and BAL is calculated.

6 If IOUT equals zero, then again, the program moves to statement number 305, where the details of runoff are written to 'results'.

7 The cumulative totals of EVAPI, PPTT, CINFIL, CUMDRN are written to 'results'.

8 Details of the runoff and water detained on the surface are written to 'results'.

9 Creation of array containing runoff data.

Chapter 3

WDATA(300,10) contains the runoff which is converted into inches for passing back to CMPHYD, which has been derived for each soil column in the subcatchment (maximum of 10), and which has been weighted according to the percentage area which that soil column occupies:

WDATA(MMM,W) = (RTOT/.0254)*(IPCAREA/100.0)

MMM	the MMMth runoff value
W	the Wth soil column
RTOT	the runoff which occurred in the period
IPCAREA	the percentage area which the soil column occupies

10 34543 CONTINUE

This marks the end of the simulation for one soil column. If there is another, then the subroutine is repeated from the place where the soil information is read in from 'data2'.

If there are no further soil columns, the subroutine proceeds out of loop number 34543.

The final operation in this subroutine is to sum the weighted runoff contained in WDATA(300,10) to derive the total runoff to be passed back to CYMPHD. Loop 76567 undertakes this calculation, and the runoff data is finally stored in DATA(300).

IR is returned to CMPHYD as the number of elements in the array DATA(300).

Chapter 4

MILHY3 : P.C. Version

4.1 Introduction

This chapter summarizes the main program changes necessary to run MILHY3 at the P.C. level. MILHY3 will run on an IBM-AT, or similar. The main changes required are related to the provision of a random number generator for the stochastic version and the conversion of mixed numeric and character arrays.

4.2 Random Number Generator

MILHY3 calls a library routine g05ddf, part of the NAG library to generate random values within a distribution determined from the mean and standard deviation entered in the 'data2' data set. These values are used to analyse the error band in the predicted runoff hydrograph, usually associated with field or instrument inaccuracies. The routine g05ddf calls in turn a routine g05caf which is machine specific.

If the stochastic version is not required, then CALL statements to the library may be simply commented out. The CALL statements are located in the SOILM subroutine. If the stochastic capability is to be retained, then another random number generator must be provided.

4.3 Character/Numeric Arrays

MILHY was originally written in FORTRAN 66, utilizing mixed character and numeric arrays. This ability was used in the 'datal' data set, where numeric and character fields are read together. At the PC-level, the character and numeric arrays must be separated. This is achieved using the least changes possible to the

program code and, therefore, is not necessarily the most efficient method.

A new common block /BLOCK4/ is introduced in routines BLKDTA, MAIN, HONDO and GIT and new CHARACTER arrays are dimensioned. In BLKDTA the variables ZALPHA and CTBLE are redefined using three new variables ZALPHA2, CTBLE1 and CTBLE2. In HONDO, these changes are pursued with changes to the READ and WRITE statements. In HPLOT, the CHARACTER arrays are dimensioned and MAX is updated for a narrower printer. A copy of the IBM version of these routines is now included.

```
C ==========================================
C
      MAIN
C
C ==========================================
C
      COMMON/BLOCK1/CTBLE(50,11),ITBLE(50,2),ZALPHA(20),
     &MAXNO,NCODE,ICC,NCOMM
C
      COMMON/BLOCK2/OCFS(300,6),DATA(310),RAIN(300),ROIN(6),
     &IEND(6),DA(6),DT(6),PEAK(6),TIME,KCODE,ICODE
C
      COMMON/BLOCK3/A(20,70),Q(20,70),DEEP(20,70),DP(20),
     &SCFS(20),C(20,6),DIST(6),SEGN(6),ISG(6),PERQ(20,70),
     &TQ(20,6),CC(20),LL(6),INRC,LRC
C
      COMMON/BLOCK4/ZALPH2(20),CTBL1(50,2),CTBL2(50,9)
      CHARACTER*1 ZALPH2,CTBL1
      CHARACTER*2 CTBL2
C
      OPEN (1,STATUS='OLD',FILE='data1')
      OPEN(25,STATUS='OLD',FILE='data2')
      OPEN(6,STATUS='NEW',FILE='results')
      NCODE=0
      ICC=0
1     NER=0
      CALL HONDO
      IF (NER) 2,2,17
2     GO TO (3,4,5,6,7,8,9,10,11,12,13,14,15,16,17), NCODE
3     TIME=DATA(1)
      KCODE=DATA(2)
      ICODE=DATA(3)
      GO TO 1
4     CALL STHYD
      GO TO 1
5     CALL CMPHYD
      GO TO 1
6     CALL PRTHYD
      GO TO 1
7     CALL HPLOT
      GO TO 1
8     CALL ADHYD
      GO TO 1
9     CALL SRC
      GO TO 1
10    CALL CMPRC
      GO TO 1
11    CALL STT
      GO TO 1
12    CALL CMPTT
      GO TO 1
13    CALL ROUTE
      GO TO 1
14    CALL RESVO
      GO TO 1
15    CALL ERROR
      GO TO 1
16    CALL SEDT
```

```
      GO TO 1
17    STOP
      END
```

```
C
C
C ====================================
C
      SUBROUTINE HONDO
C
C ====================================
C
C This subroutine reads in the data from 'datal', searches an alphanum ric
C code table to determine the NCODE of the required operation, and collects
C variables from the freefloating data field.
C
C The command table (CTBLE), integer table (ITBLE), number of commands
C (NCOMM) and alphanumeric array (ZALPHA) are initialized in BLOCK DATA
C located at the end of this listing.
C
C
      COMMON/BLOCK1/CTBLE(50,11),ITBLE(50,2),ZALPHA(20),
     &MAXNO,NCODE,ICC,NCOMM
C
      COMMON/BLOCK2/OCFS(300,6),DATA(310),RAIN(300),ROIN(6),
     &IEND(6),DA(6),DT(6) PEAK(6),TIME,KCODE,ICODE
C
      COMMON/BLOCK4/ZALPH2(20,CTBL1(50,2),CTBL2(50,9)
      CHARACTER*1 ZALPH2,CTBL1,CHAR(60),ALPHA1(2),AUXA(10),AUXB(10)
      CHARACTER*2 CTBL2,ALPHA2(9)
C
      IF (ICC) 1,1,3
C     READ IN DATA CARD
1     READ (1,42) (ALPHA1(I),I=1,2),(ALPHA2(I),I=1,9),(CHAR(I),I=1,60)
C     IF FIRST CHARACTER IS BLANK THE CARD IS A CONTINUATION OF
C     PREVIOUS CARD.
      IF (ALPHA1(1)-ZALPH2(11)) 2,9,2
2     IF (ICC) 3,3,40
C     ASTERISK IN COL. 80 MEANS SKIP TO NEW PAGE BEFORE PRINTING CARD
3     IF (CHAR(60)-ZALPH2(11)) 4,5,4
4     WRITE (6,43)
5     WRITE (6,44) (ALPHA1(I),I=1,2),(ALPHA2(I),I=1,9),(CHAR(I),I=1,60)
C     IF FIRST CHARACTER IS A *  THE PREVIOUS CARD WAS A COMMENT CARD
      IF (ALPHA1(1).NE.ZALPH2(12)) GOTO 10
6     ICC=0
      GO TO 1
9     WRITE (6,44) (ALPHA1(I),I=1,2),(ALPHA2(I),I=1,9),(CHAR(I),I=1,60)
      GO TO 24
C     SEARCH FIRST TWO ALPHAMERIC CHARACTERS TO SEE IF THEY ARE NUMBERS
10    ICC=1
      DO 12 I=1,10
      IF (ALPHA1(1).EQ.ZALPH2(I)) GOTO 15
11    IF (ALPHA1(2).EQ.ZALPH2(I)) GOTO 15
12    CONTINUE
C     STATEMENT NUMBER 7 IS BRANCHED TO IF NUMBERS ARE PRESENT
C     IF NOT NUMBER SEARCH COMMAND TABLE FOR MATCH
C     CALL FIRST 10 VALUES FROM PERMANENT DATA STORAGE
      DO 14 I=1,NCOMM
      DO 13 J=1,11
      IF (CTBL1(I,J).NE.ALPHA1(J)) GOTO 14
13    CONTINUE
```

```
      DO 131 J=1,9
      IF(CTBL2(I,J).NE.ALPHA2(J)) GOTO 14
131   CONTINUE
C     IF THIS LOOP IS COMPLETED WE HAVE COMPLETE MATCH- CALL NCODE
C     AND MAX NUMBER AND EXIT LOOP
      NCODE=ITBLE(I,1)
      MAXNO=ITBLE(I,2)
      GO TO 21
14    CONTINUE
C     IF MAJOR LOOPS FINISHED WITHOUT A MATCH WRITE ERROR MESSAGE
C     AND SET NER  = 1
      NER=1
      WRITE (6,46)
      RETURN
C     CONVERT DIGIT INPUT CODE FROM ALPHAMERIC TO INTEGER FORM
15    NCODE=GIT(ALPHA1,1,2,1.)+0.5
C     FIND MAX NUMBER OF DATA ITEMS FOR THIS NCODE
      DO 17 I=1,NCOMM
      IF (ITBLE(I,1)-NCODE) 17,16,17
16    MAXNO=ITBLE(I,2)
      GO TO 21
17    CONTINUE
C     SEARCH DATA ROUTINE
C     SEE IF ANY DATA FOR THIS CARD
      DO 19 I=1,NCOMM
      IF (ITBLE(I,1)-NCODE) 19,18,19
18    MAXNO=ITBLE(I,2)
      GO TO 20
19    CONTINUE
20    CONTINUE
21    IF (MAXNO) 23,22,23
22    RETURN
C      ZERO ARRAYS AND COUNTERS
23    DO 47 I=1,310
47    DATA (I)=0.
      NDATA=1
24    NCHAR=0
25    DO 26 I=1,10
      AUXA(I)="*"
26    AUXB(I)="*"
      IT1=1
      IT2=1
      SIGN=1.
      LDGIT=0
      KDGIT=0
C     CARRY OUT DIGIT BY DIGIT SEARCH AND ACCUMULATION
27    NCHAR=NCHAR+1
C     HAVE WE CONSIDERED ALL CHARACTERS - RETURN IF SO
      IF (NCHAR-60) 28,32,1
28    DO 29 I=1,15
      IF (CHAR(NCHAR)>EQ.ZALPH2(I)) GOTO 30
29    CONTINUE
      GO TO 32
30    GO TO (33,33,33,33,33,33,33,33,33,33,32,27,36,32,31,27), I
C     SN 39  HANDLES SIGN CONTROL ON 1130 VERSION
31    SIGN=-1.0
      GO TO 27
C     CHARACTER IS BLANK OR COMMA - DOES IT FOLLOW A DIGIT
```

```
32    GO TO (27,48), IT1
C     CHARACTER IS A DIGIT - HAS A DECIMAL BEEN ENCOUNTERED
33    GO TO (34,35), IT2
34    LDGIT=LDGIT+1
      IT1=2
      AUXA(LDGIT)=CHAR(NCHAR)
      GO TO 27
35    KDGIT=KDGIT+1
      AUXB(KDGIT)=CHAR(NCHAR)
      GO TO 27
C     CHARACTER IS A DECIMAL - DOES IT FOLLOW A DIGIT
36    GO TO (37,38), IT1
37    IT1=2
      LDGIT=1
38    IT2=2
      GO TO 27
C     ROUTINE TO CONVERT ALPHABETIC ARRAY TO FLOATING POINT NUMBER
48    DATA (NDATA)=GIT(AUXA,1,LDGIT,1.)+GIT(AUXB,1,10,0.)
      DATA (NDATA)=DATA(NDATA)*SIGN
C     IS ALL DATA FURNISHED  YES-RETURN  NO INCREASE N DATA KEEP ON
      IF (NDATA-MAXNO) 41,39,39
39    ICC=0
40    RETURN
41    NDATA=NDATA+1
      GO TO 25
C
42    FORMAT (2A1,9A2,60A1)
43    FORMAT (1H1)
44    FORMAT (5X,2A1,9A2,60A1)
46    FORMAT (10X,20HCOMMAND NOT IN TABLE)
      END
```

```
C
C
C ==================================== =====
C
      FUNCTION GIT (TCARD,J,JLAST,SHIFT)
C
C ==========================================
C
C Converts alphabetic array to floating point number
C
      CHARACTER*1  TCARD(10), A(10),TTEST
      DATA A(1)/1H1/,A(2)/1H2/,A(3)/1H3/,A(4)/1H4/,A(5)/1H5/,A(6)/1H6/
      DATA A(7)/1H7/,A(8)/1H8/,A(9)/1H9/,A(10)/1H0/
C
      GIT=0.
      TEN=10.
      SUM=0.
      DO 3 JNOW=J,JLAST
      TTEST=TCARD(JNOW)
C     CHECK FOR LAST ENTRY
      IF (TTEST.EQ."*".) GO TO 4
C     FIND NUMBER AND COMPUTE VALUE
      DO 2 NUMB=1,10
      IF (TTEST-A(NUMB)) 2,1,2
1     ZTEST=NUMB
      IF (ZTEST.EQ.10.) ZTEST=0.
      SUM=SUM*TEN+ZTEST
      GO TO 3
2     CONTINUE
3     CONTINUE
4     IF (SHIFT) 6,5,6
5     FI=JNOW-1
      SUM=SUM*(0.1**FI)
6     GIT=SUM
      RETURN
      END
```

```
C
C
C ==============================================
C
      SUBROUTINE HPLOT
C
C ==============================================
C
C     THIS SUBROUTINE PLOTS EITHER 1 OR 2 HYDROGRAPHS ON A SET OF AXIS
C
      COMMON/BLOCK2/OCFS(300,6),DATA(310),RAIN(300),ROIN(6),
     &IEND(6),DA(6),DT(6),PEAK(6),TIME,KCODE,ICODE
      CHARACTER*1 ZERO,PLUS,BLANK,DASH,DOT
      CHARACTER*1 CCFS(132)
C
      ID1=DATA(1)
      ID2=DATA(2)
      DATA ZERO, PLUS, BLANK, DASH, DOT/'0','+',' ','-','.'/
      MAX=69
      J=1
C     ARE THERE 1 OR 2 HYDROGRAPHS
      IF (ID2) 1,1,2
C     DETERMINE HIGHEST PEAK IF 2 HYDROGRAPHS
1     QMAX=PEAK(ID1)
      GO TO 14
2     IF (PEAK(ID1)-PEAK(ID2)) 3,3,4
3     QMAX=PEAK(ID2)
      GO TO 5
4     QMAX=PEAK(ID1)
C     IF 2 HYDROGRAPHS DETERMINE LARGEST DT AND INTERPOLATE OTHER
C     HYDROGRAPH IF NECESSARY
5     IF (DT(ID1)-DT(ID2)) 6,13,7
6     L=ID1
      K=ID2
      GO TO 8
7     L=ID2
      K=ID1
8     M=IEND(L)
      TID=DT(K)
      TIDH=0.
      DO 11 I=2,M
      TIDH=TIDH+DT(L)
      IF (TID-TIDH) 10,9,11
9     J=J+1
      CFS(J)=OCFS(I,L)
      TID=TID+DT(K)
      GO TO 11
10    J=J+1
      CFS(J)=OCFS(I-1,L)+((TID-TIDH+DT(L))/DT(L))*(OCFS(I,L)-OCFS(I-1,L)
     &)
      TID=TID+DT(K)
11    CONTINUE
      IEND(L)=J
      DT(L)=DT(K)
      DO 12 I=2,J
12    OCFS(I,L)=CFS(I)
13    IF (IEND(ID1)-IEND(ID2)) 14,14,15
```

```
14    M=IEND(ID1)
      GO TO 16
15    M=IEND(ID2)
16    XM = M
C     DETERMINE TIME SCALE
      XSCL = XM / 120.
      YSCL=QMAX/50.
C     PLOT HYDROGRAPHS
      DO 20 I=1,MAX
20    CFS(I)=DASH
      IF(ICODE.EQ.0)GO TO 49
      WRITE(6,50)
50    FORMAT(T2,"FLOW RATE (CMS)")
      QMAX1=QMAX*0.02832
      WRITE(6,41)QMAX1,DOT,(CFS(I),I=1,MAX),DOT
      GO TO 51
49    WRITE(6,48)
48    FORMAT(T2,'FLOW RATE (CFS)')
      WRITE(6,41)QMAX,DOT,(CFS(I),I=1,MAX),DOT
51    Q1=QMAX
      J1=10
      DO 37 J=1,50
      IF (J-J1) 23,21,23
21    DO 22 I=1,MAX
22    CFS(I)=DASH
      GO TO 25
23    DO 24 I=1,MAX
24    CFS(I)=BLANK
25    Q2=Q1-YSCL
      DO 28 I=2,M
      IF (OCFS(I,ID1)-Q1) 26,27,28
26    IF (OCFS(I,ID1)-Q2) 28,28,27
27    XI = I
      K = XI / XSCL + 1.
      CFS(K)=ZERO
28    CONTINUE
      WRITE (6,44) DOT,(CFS(I),I=1,MAX),DOT
      IF (ID2) 34,34,29
29    DO 18 I = 1, MAX
18    CFS(I) = BLANK
      DO 33 I=1,M
      IF (OCFS(I,ID2)-Q1) 30,31,33
30    IF (OCFS(I,ID2)-Q2) 33,33,31
31    XI = I
      K = XI / XSCL + 1.
      CFS(K)=PLUS
33    CONTINUE
      WRITE (6,42) (CFS(I),I=1,MAX)
34    IF (J-J1) 36,35,36
35    J1=J1+10
      IF(ICODE.EQ.0)GO TO 52
      QD=Q2*0.02832
      WRITE(6,43)QD
      GO TO 36
52    WRITE(6,43)Q2
36    Q1=Q2
37    CONTINUE
      CFS(1)=TIME
```

```
      DTT=DT(ID1)*(XM - 1.) / 12.
C     PUT TIME ARRAY IN CFS AND WRITE TIME SCALE
      DO 38 I=2,13
38    CFS(I)=CFS(I-1)+DTT
      WRITE (6,45) (CFS(I),I=1,13)
      WRITE (6,46)
      RETURN
C
41    FORMAT(1X,F7.0,123A1)
42    FORMAT(1H+,8X,121A1)
43    FORMAT (1H+,F7.0)
44    FORMAT(8X,123A1)
45    FORMAT(T3,13F10.2)
46    FORMAT(49X,'TIME HOURS'///)
      END
```

```
C ========================================
C
      BLOCK DATA
C
C ========================================

C     BLOCK DATA SUBPROGRAM UZED TO INITIALIZE ZALPHA,CTBLE,ITBLE
C     AND NCOMM.

      COMMON/BLOCK1/CTBLE(50,11),ITBLE(50,2),ZALPHA(20),
     &MAXNO,NCODE,ICC,NCOMM
      COMMON/BLOCL4/ZALPH2(70),CTBL1(50,2),CTBL2(50,9)
      CHARACTER*1 ZALPH2,CTBL1
      CHARACTER*2 CTBL2

      DATA ZALPH2/1H1,1H2,1H3,1H4,1H5,1H6,1H7,1H8,1H9,1H0,1H ,
     &1H*,1H.,1H,,1H-,1H ,1H ,1H ,1H ,1H /

      DATA NCOMM/15/

      DATA CTBL1/1HS,1HS,1HC,1HP,1HP,1HA,1HS,1HC,1HS,1HC,1HR,
     &1HR,1HE,1HS,1HF,35*1H ,
     &1HT,1HT,1HO,1HR,1HL,1HD,1HT,1HO,1HT,1HO,1HO,1HO,1HR,
     &1HE,1HI,35*1H /
C
      DATA CTBL2/
     &2HAR,2HOR,2HMP,2HIN,2HOT,2HD ,2HOR,2HMP,2HOR,2HMP,
     &2HUT,2HUT,2HRO,2HDI,2HNI,35*2H  ,
     &2HT ,2HE ,2HUT,2HT ,2H H,2HHY,2HE ,2HUT,2HE ,2HUT,
     &2HE ,2HE ,2HR ,2HME,2HSH,35*2H  ,
     &2H  ,2HHY,2HE ,2HHY,2HYD,2HD ,2HRA,2HE ,2HTR,2HE ,
     &2H  ,2HRE,2HAN,2HNT,2H  ,35*2H  ,
     &2H  ,2HD ,2HHY,2HD ,2H  ,2H  ,2HTI,2HRA,2HAV,2HTR,
     &2H  ,2HSE,2HAL,2H Y,2H  ,35*2H  ,
     &2H  ,2H  ,2HD ,2H  ,2H  ,2H  ,2HNG,2HTI,2HEL,2HAV,
     &2H  ,2HRV,2HYS,2HIE,2H  ,35*2H  ,
     &6*2H  ,2H C,2HNG,2H T,2HEL,2H  ,2HOI,2HIS,2HLD,36*2H  ,
     &6*2H  ,2HUR,2H C,2HIM,2H T,2H  ,2HR ,38*2H  ,
     &6*2H  ,2HVE,2HUR,2HE ,2HIM,40*2H  ,
     &7*2H  ,2HVE,2H  ,2HE ,40*2H  /

      DATA ITBLE/1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,35*1H ,
     &3,310,310,4,2,4,100,310,100,8,7,25,2,5,0,35*1H /
      END
```

Chapter 5

```
C =========================================================================
C
C              MILHY3 - a mathematical flood forecasting model for
C                       ungauged catchments
C
C =========================================================================
C
C Program:      MILHY3
C               (MILHY2) including two-stage channel modelling.
C               With improved out-of-bank flood modelling incorporating
C               MOMENTUM EXCHANGE between in and out of bank flows and
C               MULTIPLE ROUTING REACHES -allowing separate pathways for
C               channel and floodplain flows.
C
C Coded by:     Laura Baird
C               University of Bristol
C
C NOTES         Upgraded subroutines
C                       ADHYD
C                       STHYD
C                       CMPRC
C                       STT
C                       CMPTT
C                       ROUTE
C                       PRTHYD
C                       BLKDTA
C
C Notes         The structure of the code remains unaltered.
C               All additional computations occur within existing
C               subroutines.
C               HOWEVER, there are significant changes in the manner in
C               which the data set DATA1 must be set out to facilitate
C               utilisation of the new capabilities.
C               All punch card capabilities have been removed.
C
C UNITS         All computations (except in the infiltration algorithm)
C               are carried out in imperial units, irrespective of KCODE
C               and ICODE.
C ------------------------------------------------------------------------
C
C
      COMMON/BLOCK1/CTBLE(50,11),ITBLE(50,2),ZALPHA(20),
     &MAXNO,NCODE,ICC,NCOMM
C
      COMMON/BLOCK2/OCFS(300,6),DATA(310),RAIN(300),ROIN(6),
     &IEND(6),DA(6),DT(6),PEAK(6),TIME,KCODE,ICODE
C
      COMMON/BLOCK3/A(20,70),Q(20,70),DEEP(20,70),DP(20),
     &SCFS(20),C(20,6),DIST(6),SEGN(6),ISG(6),PERQ(20,70),
     &TQ(20,6),CC(20),LL(6),INRC,LRC
C
C Definition of variables in common 1
C control variables
C CTBLE   Command table
C ITBLE   Integer table
C ZALPHA  Alphanumeric code table
C MAXNO   Max. number of data expected for any command
C NCODE   Number of command
```

```
C ICC     Continuation line
C NCOMM   Total number of legal commands
C
C Definition of variables in common 2
C hydrograph variables
C OCFS    Hydrograph discharge
C DATA    Data associated with each command
C RAIN    Cumulative precipitation values
C ROIN    Volume of discharge hydrograph
C         note: this variable is no longer divided by area
C IEND    Number of points in the hydrograph
C DA      Drainage area
C DT      Time increment for rainfall or discharge
C PEAK    Peak discharge for hydrograph
C TIME    Start time of simulation
C KCODE   Measurement unit of input
C                0 - imperial
C            not 0 - metric
C ICODE   Measurement unit of output
C                0 - imperial
C            not 0 - metric
C
C Definition of variables in common 3
C rating curve and routing variables
C A      Cross-sectional area
C Q      Discharge
C DEEP   Elevation
C SCFS   Discharge from previously computed raing curve
C C      Absolute stage elevations
C DIST   Flow segment width
C SEGN   Manning's n for flow segment
C ISG    Last elevation input in flow segment
C PERQ   Percentage discharge in flow segment
C TQ     Total discharge
C CC     Travel time  coefficient
C LL     Number of zero discharge values in rating curve segment
C INRC   Inflow rating curve identifier (multiple routing)
C LRC    Outflow rating curve identifier (multiple routing)

      OPEN (1,STATUS='OLD',FILE='data1')
      OPEN(25,STATUS='OLD',FILE='data2')
      OPEN(6,STATUS='NEW',FILE='results')
      NCODE=0
      ICC=0
1     NER=0
      CALL HONDO
      IF (NER) 2,2,17
2     GO TO (3,4,5,6,7,8,9,10,11,12,13,14,15,16,17), NCODE
3     TIME=DATA(1)
      KCODE=DATA(2)
      ICODE=DATA(3)
      GO TO 1
4     CALL STHYD
      GO TO 1
5     CALL CMPHYD
      GO TO 1
6     CALL PRTHYD
      GO TO 1
```

```
7     CALL HPLOT
      GO TO 1
8     CALL ADHYD
      GO TO 1
9     CALL SRC
      GO TO 1
10    CALL CMPRC
      GO TO 1
11    CALL STT
      GO TO 1
12    CALL CMPTT
      GO TO 1
13    CALL ROUTE
      GO TO 1
14    CALL RESVO
      GO TO 1
15    CALL ERROR
      GO TO 1
16    CALL SEDT
      GO TO 1
17    STOP
      END
C
C
C ======================================
C
      SUBROUTINE HONDO
C
C ======================================
C
C This subroutine reads in the data from 'data1', searches an alphanumeric
C code table to determine the NCODE of the required operation, and collects
C variables from the freefloating data field.
C
C The command table (CTBLE), integer table (ITBLE), number of commands
C (NCOMM) and alphanumeric array (ZALPHA) are initialized in BLOCK DATA
C located at the end of this listing.
C
C
      COMMON/BLOCK1/CTBLE(50,11),ITBLE(50,2),ZALPHA(20),
     &MAXNO,NCODE,ICC,NCOMM
C
      COMMON/BLOCK2/OCFS(300,6),DATA(310),RAIN(300),ROIN(6),
     &IEND(6),DA(6),DT(6),PEAK(6),TIME,KCODE,ICODE
C
      DIMENSION CHAR(60), ALPHA(11),AUXA(10),AUXB(10)
C
      IF (ICC) 1,1,3
C     READ IN DATA CARD
1     READ (1,42) (ALPHA(I),I=1,11),(CHAR(I),I=1,60)
C     IF FIRST CHARACTER IS BLANK THE CARD IS A CONTINUATION OF
C     PREVIOUS CARD.
      IF (ALPHA(1)-ZALPHA(11)) 2,9,2
2     IF (ICC) 3,3,40
C     ASTERISK IN COL. 80 MEANS SKIP TO NEW PAGE BEFORE PRINTING CARD
3     IF (CHAR(60)-ZALPHA(11)) 4,5,4
4     WRITE (6,43)
5     WRITE (6,44) (ALPHA(I),I=1,11),(CHAR(I),I=1,60)
```

```
C     IF FIRST CHARACTER IS A *  THE PREVIOUS CARD WAS A COMMENT CARD
      IF (ALPHA(1)-ZALPHA(12)) 10,6,10
6     ICC=0
      GO TO 1
9     WRITE (6,44) (ALPHA(I),I=1,11),(CHAR(I),I=1,60)
      GO TO 24
C     SEARCH FIRST TWO ALPHAMERIC CHARACTERS TO SEE IF THEY ARE NUMBERS
10    ICC=1
      DO 12 I=1,10
      IF (ALPHA(1)-ZALPHA(I)) 11,15,11
11    IF (ALPHA(2)-ZALPHA(I)) 12,15,12
12    CONTINUE
C     STATEMENT NUMBER 7 IS BRANCHED TO IF NUMBERS ARE PRESENT
C     IF NOT NUMBER SEARCH COMMAND TABLE FOR MATCH
C     CALL FIRST 10 VALUES FROM PERMANENT DATA STORAGE
      DO 14 I=1,NCOMM
      DO 13 J=1,11
      IF (CTBLE(I,J)-ALPHA(J)) 14,13,14
13    CONTINUE
C     IF THIS LOOP IS COMPLETED WE HAVE COMPLETE MATCH- CALL NCODE
C     AND MAX NUMBER AND EXIT LOOP
      NCODE=ITBLE(I,1)
      MAXNO=ITBLE(I,2)
      GO TO 21
14    CONTINUE
C     IF MAJOR LOOPS FINISHED WITHOUT A MATCH WRITE ERROR MESSAGE
C     AND SET NER  = 1
      NER=1
      WRITE (6,46)
      RETURN
C     CONVERT DIGIT INPUT CODE FROM ALPHAMERIC TO INTEGER FORM
15    NCODE=GIT(ALPHA,1,2,1.)+0.5
C     FIND MAX NUMBER OF DATA ITEMS FOR THIS NCODE
      DO 17 I=1,NCOMM
      IF (ITBLE(I,1)-NCODE) 17,16,17
16    MAXNO=ITBLE(I,2)
      GO TO 21
17    CONTINUE
C     SEARCH DATA ROUTINE
C     SEE IF ANY DATA FOR THIS CARD
      DO 19 I=1,NCOMM
      IF (ITBLE(I,1)-NCODE) 19,18,19
18    MAXNO=ITBLE(I,2)
      GO TO 20
19    CONTINUE
20    CONTINUE
21    IF (MAXNO) 23,22,23
22    RETURN
C      ZERO ARRAYS AND COUNTERS
23    DO 47 I=1,310
47    DATA (I)=0.
      NDATA=1
24    NCHAR=0
25    DO 26 I=1,10
      AUXA(I)=0.
26    AUXB(I)=0.
      IT1=1
      IT2=1
```

```
      SIGN=1.
      LDGIT=0
      KDGIT=0
C     CARRY OUT DIGIT BY DIGIT SEARCH AND ACCUMULATION
27    NCHAR=NCHAR+1
C     HAVE WE CONSIDERED ALL CHARACTERS - RETURN IF SO
      IF (NCHAR-60) 28,32,1
28    DO 29 I=1,15
      IF (CHAR(NCHAR)-ZALPHA(I)) 29,30,29
29    CONTINUE
      GO TO 32
30    GO TO (33,33,33,33,33,33,33,33,33,33,32,27,36,32,31,27), I
C     SN 39  HANDLES SIGN CONTROL ON 1130 VERSION
31    SIGN=-1.0
      GO TO 27
C     CHARACTER IS BLANK OR COMMA - DOES IT FOLLOW A DIGIT
32    GO TO (27,48), IT1
C     CHARACTER IS A DIGIT - HAS A DECIMAL BEEN ENCOUNTERED
33    GO TO (34,35), IT2
34    LDGIT=LDGIT+1
      IT1=2
      AUXA(LDGIT)=CHAR(NCHAR)
      GO TO 27
35    KDGIT=KDGIT+1
      AUXB(KDGIT)=CHAR(NCHAR)
      GO TO 27
C     CHARACTER IS A DECIMAL - DOES IT FOLLOW A DIGIT
36    GO TO (37,38), IT1
37    IT1=2
      LDGIT=1
38    IT2=2
      GO TO 27
C     ROUTINE TO CONVERT ALPHABETIC ARRAY TO FLOATING POINT NUMBER
48    DATA (NDATA)=GIT(AUXA,1,LDGIT,1.)+GIT(AUXB,1,10,0.)
      DATA (NDATA)=DATA(NDATA)*SIGN
C     IS ALL DATA FURNISHED  YES-RETURN  NO INCREASE N DATA KEEP ON
      IF (NDATA-MAXNO) 41,39,39
39    ICC=0
40    RETURN
41    NDATA=NDATA+1
      GO TO 25
C
42    FORMAT (2A1,9A2,60A1)
43    FORMAT (1H1)
44    FORMAT (5X,2A1,9A2,60A1)
46    FORMAT (10X,20HCOMMAND NOT IN TABLE)
      END
C
C
C ======================================
C
       FUNCTION GIT (TCARD,J,JLAST,SHIFT)
C
C ======================================
C
C Converts alphabetic array to floating point number
C
       DIMENSION TCARD(10), A(10)
```

```
      DATA A(1)/1H1/,A(2)/1H2/,A(3)/1H3/,A(4)/1H4/,A(5)/1H5/,A(6)/1H6/
      DATA A(7)/1H7/,A(8)/1H8/,A(9)/1H9/,A(10)/1H0/
C
      GIT=0.
      TEN=10.
      SUM=0.
      DO 3 JNOW=J,JLAST
      TTEST=TCARD(JNOW)
C     CHECK FOR LAST ENTRY
      IF (TTEST.EQ.0.) GO TO 4
C     FIND NUMBER AND COMPUTE VALUE
      DO 2 NUMB=1,10
      IF (TTEST-A(NUMB)) 2,1,2
1     ZTEST=NUMB
      IF (ZTEST.EQ.10.) ZTEST=0.
      SUM=SUM*TEN+ZTEST
      GO TO 3
2     CONTINUE
3     CONTINUE
4     IF (SHIFT) 6,5,6
5     FI=JNOW-1
      SUM=SUM*(0.1**FI)
6     GIT=SUM
      RETURN
      END
C
C
C ======================================
C
      SUBROUTINE STHYD
C
C ======================================
C
C     THIS SUBROUTINE STORES THE COORDINATES OF HYDROGRAPHS,
C     AND ADDS BASEFLOW TO HYDROGRAPH STORED
C
      COMMON/BLOCK2/OCFS(300,6),DATA(310),RAIN(300),ROIN(6),
     &IEND(6),DA(6),DT(6),PEAK(6),TIME,KCODE,ICODE
C
      ID=DATA(1)
      NHD=DATA(2)
      DT(ID)=DATA(3)
      IF(KCODE.EQ.0)GO TO 10
      DATA(4)=DATA(4)/2.590
      DATA(5)=DATA(5)/0.02832
      DO 11 J=6,306
11    DATA(J)=DATA(J)/.02832
10    DA(ID)=DATA(4)
      BSF=DATA(5)
C     BASEFLOW
      J=6
C     REMAINING DATA ARE FLOW RATES
      OCFS(1,ID)=DATA(J)+BSF
      PEAK(ID) = 1.
      RO = DATA(J)
      DO 4 I=2,300
      J=J+1
      OCFS(I,ID)=DATA(J)+BSF
```

```
      RO = RO + OCFS(I,ID)
C     IS FLOW RECEDING
      IF (OCFS(I,ID)-OCFS(I-1,ID)) 1,2,2
C     HAS FLOW RECEDED TO CUTOFF RATE
1     IF (OCFS(I,ID)) 5,5,4
C     DETERMINE PEAK FLOW
2     IF(OCFS(I,ID) - PEAK(ID)) 4,4,3
3     PEAK(ID) = OCFS(I,ID)
4     CONTINUE
5     IEND(ID)=I-1
      M=IEND(ID)
      ROIN(ID)=RO*DT(ID)*3600
      RETURN
      END
C
C
C =======================================
C
      SUBROUTINE CMPHYD
C
C =======================================
C
C This subroutine develops a unit hydrograph, converts rainfall data
C into runoff by calling the soil moisture finite difference model,
C or the Curve Number routine,
C and sums these two to produce the storm runoff hydrograph.
C
      COMMON/BLOCK2/OCFS(300,6),DATA(310),RAIN(300),ROIN(6),
     &IEND(6),DA(6),DT(6),PEAK(6),TIME,KCODE,ICODE
C
      DIMENSION CFS(300)
C     CFS    Unit hydrograph discharge
      TEMP=0.
C
C Input data read into subroutine
      ID=DATA(1)
      NHD=DATA(2)
      DT(ID)=DATA(3)
      IF(KCODE.NE.0)THEN
C            Convert metric to imperial
             DATA(4)=DATA(4)/2.590
             IF(DATA(6).LT.0)GO TO 40
             DATA(6)=DATA(6)/0.3048
             DATA(7)=DATA(7)/1.6
      ENDIF
40    DA(ID)=DATA(4)
      CN=DATA(5)
C Data items 6 and 7 normally hold watershed height and length and
C from these the constants XK(recession constant) and Tp(time to peak)
C can be calculated.
C If XK and Tp are known however, they can be entered instead
C and a negative sign is put before their values.
      IF (DATA(6).LT.0.)THEN
         XK=-DATA(6)
         TP=-DATA(7)
      ELSE
         HT=DATA(6)
         XL=DATA(7)
```

```
           SLOPE=HT/XL
           XLDW=(XL**2.)/DA(ID)
           XK=27.0*(DA(ID)**.231)*(SLOPE**(-.777))*(XLDW**.124)
           TP=4.63*(DA(ID)**.422)*(SLOPE**(-.46))*(XLDW**.133)
        ENDIF
C The storm runoff array and unit hydrograph array are intialised to 0,
C  and peak of hydrograph to 1
          DO 4 I=1,300
          CFS(I)=0
4         OCFS(I,ID)=0.
          PEAK(ID)=1.
C Compute unit hydrograph parameters
C Compute 'N' by iteration
        XN=5.0
        XKTP=XK/TP
          DO 6 I=1,50
          TINF=1.+SQRT(1./(XN-1.))
          XN1=.05/(XKTP*(ALOG(TINF/(TINF+.05))+.05))+1.
          DIFF=ABS(XN1-XN)
          IF (DIFF-.001) 7,7,5
5         XN=XN1
6         CONTINUE
        WRITE (6,29)
29      FORMAT(' N DID NOT CONVERGE AFTER 50 ITERATIONS.')
        GO TO 28
C Compute 'C1'
/       DELT=TINF/100.
        TC1=0.
        XN1P=XN-1.
        XN1M=1.-XN
          DO 8 I=2,101
          TC1=TC1+DELT
8         CFS(I)=(TC1**XN1P)*EXP(XN1M*(TC1-1.))
        SUM=CFS(101)/2.
          DO 9 I=2,100
9         SUM=SUM+CFS(I)
        C1=SUM*DELT
C Compute 'B'
        CFSII=CFS(101)
        TTINF=TINF*TP
        TREC1=TTINF+2.*XK
        EEE=EXP((TTINF-TREC1)/XK)
        XK1=3.*XK
        B=645.333/(C1+CFSII*(XKTP*(1.-EEE)+EEE*(XK1/TP)))
C Compute 'QP' and 'CFSI'
        QP=(B*DA(ID))/TP
        CFSI=QP*CFS(101)
        CFSR1=CFSI*EEE
        IF(ICODE.EQ.0)GO TO 45
        QP1=QP*.02832
        WRITE(6,38)XN,QP1
38      FORMAT(' Shape constant, N = ',F6.3/' Unit peak = ',F10.1,1X
       &,'cms'/)
        GO TO 44
45      WRITE (6,30) XN,QP
30      FORMAT(' Shape constant, N = ',F6.3/' Unit peak = ',F10.1,1X
       *,'cms'/)
C
```

```
44    CONTINUE
C
C Determine the incremental runoff
C
      IF(KCODE.NE.0)THEN
          IF(DATA(8).LT.0)GO TO 13
C             Convert rainfall data from mm to inches.
           DO 34 K=8,308
34           DATA(K)=DATA(K)/25.4
      ENDIF
35    J=8
      IF (DATA(J)) 13,10,10
10    RAIN(1)=DATA(J)
        DO 11 I=2,300
        J=J+1
        RAIN(I)=DATA(J)
        IF (RAIN(I)-RAIN(I-1)) 12,11,11
11      CONTINUE
12    NUMB=I-1
C
C     Curve number routine
13    IF(CN.LE.0)GOTO 201
C     STORAGE
      R=1000./CN-10
      B1=.2*R
      DO 15 I=1,NUMB
      IF(RAIN(I)-B1)33,33,14
33    DATA(I)=0
      Q1=0
      GOTO 15
14    Q2=((RAIN(I)-B1)**2.)/(RAIN(I)+.8*R)
      DATA(I)=Q2-Q1
      Q1=Q2
15    CONTINUE
      GOTO 202
C
C     Soil moisture algorithm
201   DO 5555 I=1,300
5555  DATA(1)=0
      TEMP=DT(ID)
C
      CALL SOILM(TEMP,NUMB,RAIN,DATA)

C Subroutine returns a vector of runoff values from the soil moisture model
C If no runoff has been generated by the soil water model, then the simulation
C stops.

      DO 100 I=1,NUMB
      IF(DATA(I).EQ.0.)GOTO 100
      GOTO 200
100   CONTINUE
      WRITE(6,300)
300   FORMAT(' Soil water model generated no runoff'/
     &' Simulation terminates')
      STOP
200   CONTINUE
C
C Compute unit hydrograph
```

```
202      T2=0.
         CFS(1)=0.
         DO 20 I=2,300
         T2=T2+DT(ID)
         IF (T2-TTINF) 16,16,17
16       CFS(I)=QP*((T2/TP)**XN1P)*EXP(XN1M*(T2/TP-1.))
         GO TO 20
17       IF (T2-TREC1) 18,18,19
18       CFS(I)=CFSI*EXP((TTINF-T2)/XK)
         GO TO 20
19       CFS(I)=CFSR1*EXP((TREC1-T2)/XK1)
         IF (CFS(I)-1.) 21,21,20
20       CONTINUE
         I=300
21       ICND=I
C
C
C Compute the storm runoff hydrograph by summing the unit hydrograph and
C the runoff from the soil moisture model.
C
C
         DO 24 J=2,NUMB
         N=J+ICND-2
         IF (N-300) 23,23,22
22       N=300
23       I = 2
           DO 24 K= J,N
           OCFS(K,ID)=OCFS(K,ID)+DATA(J)*CFS(I)
           I=I+1
24         CONTINUE
C
C Compute the runoff volume and determine the peak.
C
C
       RO = 0.
         DO 26 I = 2,N
         RO = RO + OCFS(I,ID)
         IF (OCFS(I,ID)-PEAK(ID))26,26,25
25       PEAK(ID)= OCFS(I,ID)
26       CONTINUE
       IEND (ID) = N
       ROIN(ID)=RO*DT(ID)*3600
C
28     RETURN
       END
C
C
C ==========================================
C
       SUBROUTINE SOILM(DT,IR,CUMRAIN,DATA)
C
C ==========================================
C
C A physically based parameter infiltration model which simulates near surfac
C soil water movement, and hence runoff.
C
C Variables used in this subroutine
C
```

```
C      TIME          Time when simulation begins (hours).
C      SR1           Soil water content at saturation  layer 1.
C      SR2                                  (m3/m3)  layer 2.
C      SR3                                           layer 3.
C      NLA           Number of cells in layer 1.
C      NLB           Number of cells in layer 2.
C      NL            Total number of cells in column
C      SATCON        Saturated permeability (ms-1)  layer 1.
C      SATCON2                                      layer 2.
C      SATCON3                                      layer 3.
C      EMAX          Maximum evaporation during the day (ms-1).
C      SIMDUR        Simulation duration (hours).
C      DETCAP        Surface detention capacity (m).
C      AF            Simulation iteration period (secs).
C      WT            Write-out time period (hrs).
C      THETA         Initial soil water content for each cell (m3/m3).
C      TCOM          Thickness of each cell.
C      ALR           Rain start time (hours).
C      AMR           Rain stop time.
C      NQ            Number of observations on suction moisture curve.
C      X             Moisture values....layer 1 (m3/m3).
C      Y             Suction values.....layer 1 (bars).
C      X2                               layer 2.
C      Y2                               layer 2.
C      X3                               layer 3.
C      Y3                               layer 3.
C      IR             Number of rainfall observations.
C      DT             Rainfall data time increments (hours).
C      CUMRAIN        Cumulative rainfall data at DT time increments (inches).
C      NSCOL          Number of soil columns.
C      IPCAREA        Percent area of soil column.
C      IOUT           Determines amount of output.
C                          1 - total output
C                          0 - shorter
C
C   Note:
C      If SR1, SR2, SR3, SATCON, SATCON2, SATCON3, DETCAP, THETA, X, X2, or X3
C      are proceeded by an 'A', then the variable type is double precision
C      rather than real.  If SR1, SR2, SR3, SATCON, SATCON2, SATCON2, DETCAP,
C      OR THETA are preceeded by an 'S',then the variable represents the
C      standard deviation of that particular soil hydrological characteristic.
C
C      SCURV1         Standard deviation of soil moisture curve for layer 1
C      SCURV2                                                       layer 2
C      SCURV3                                                       layer 3
C
C
C         ---------------
C         INITIAL SECTION
C         ---------------
C
C
       DIMENSION FLUX(20),TCOM(20),SWP(20),THETA(20),COND(20)
       DIMENSION VOL(20),ANFLUX(20),AVCOND(20),DEPTH(20),DIST(20)
       DIMENSION X(20),Y(20),G(20),GZ(20)
       DIMENSION CUMRAIN(251),Z(20),PPT(250)
       DIMENSION DATA(300),WDATA(300,10),HPOT(20)
       DIMENSION G2(20),Y2(20),X2(20),GZ2(20),Z2(20)
```

```
      DIMENSION G3(20),Y3(20),X3(20),GZ3(20),Z3(20)
      DIMENSION RSAT(20)
      DIMENSION AX(20),AX2(20),AX3(20),ATHETA(20)
      DIMENSION XNEW(20),YNEW(20),X2NEW(20),Y2NEW(20),
     &         X3NEW(20),Y3NEW(20)
      DOUBLE PRECISION G05DDF
      DOUBLE PRECISION DLOG10
      DOUBLE PRECISION ATHETA,AX,AX2,AX3,ADETCAP,ASR1,ASR2,ASR3,
     *   ASATCON,ASATCON2,ASATCON3,BSATCON,BSATCON2,BSATCON3,
     *   SDETCAP,SSR1,SSR2,SSR3,STHETA,SSATCON,SSATCON2,SSATCON3,
     *   SCURV1,SCURV2,SCURV3
C
C        READ IN DATA
C        ------------
C
      READ(25,*)TIME,ALR,AMR,SIMDUR
      READ(25,*)IOUT
      READ(25,*)AF,WT
      READ(25,*)NSCOL
C
C The array RAIN which is passed to the subroutine as a cumulative
C rainfall total is in inches.This has to be transfered to array
C PPT which is in m and represents the total for each time increment.
      IRR=IR-1
      DO 100 I=1,IRR
100   PPT(I)=(CUMRAIN(I+1)-CUMRAIN(I))*.0254
      DO 34543 W=1,NSCOL
C     For each soil column in turn, read in data and proceed through
C     simulation to determine runoff
      READ(25,*)IPCAREA
      READ(25,*)NL,NLA,NLB
      READ(25,*)(TCOM(I),I=1,NL)
      READ(25,*)EMAX,ADETCAP,SDETCAP
      READ(25,*)ASR1,SSR1,ASR2,SSR2,ASR3,SSR3
      READ(25,*)ASATCON,SSATCON,ASATCON2,SSATCON2,ASATCON3,SSATCON3
      READ(25,*)(ATHETA(I),I=1,NL)
      READ(25,*)STHETA
      READ(25,*)NQ
      READ(25,*)(AX(I),I=1,NQ)
      READ(25,*)(Y(I),I=1,NQ)
      READ(25,*)SCURV1
      READ(25,*)(AX2(I),I=1,NQ)
      READ(25,*)(Y2(I),I=1,NQ)
      READ(25,*)SCURV2
      READ(25,*)(AX3(I),I=1,NQ)
      READ(25,*)(Y3(I),I=1,NQ)
      READ(25,*)SCURV3
      NQJ=NQ
      NLL=NL+1
      IF(AMR.LT.ALR)THEN
          AMR=AMR+24.0
      ENDIF
C
C       CHECK DATA INPUTS
C       -----------------
C
      NERROR=0
C Check number of cells in soil column
```

```
      IF(NLA+NLB.GE.NL)THEN
         WRITE(6,1015)
1015     FORMAT(' Error-NLA,NLB,NL')
         NERROR=NERROR+1
      ENDIF
C
C Check dimensions of input vectors
      IF(NQ.GT.20.OR.NL.GT.20.OR.IR.GT.250)THEN
         WRITE(6,1020)
1020     FORMAT(' Error-limit exceeded,NQ,NL,IR')
         NERROR=NERROR+1
      ENDIF
C
C Check rainfall passed from CMPHYD
      KN=IR-1
      DO 50 I=1,KN
         IF(CUMRAIN(I+1).LT.CUMRAIN(I))THEN
            WRITE(6,1030)
1030        FORMAT(' Error-not cumulative rainfall totals')
            NERROR=NERROR+1
         ENDIF
50     CONTINUE
C
C Check that initial moisture content of each cell lies within the range of
C the suction moisture curve and does not exceed stated saturated moisture
C content.
      DO 51 I=1,NLA
         IF(ATHETA(I).GT.ASR1)THEN
            WRITE(6,1050)
1050        FORMAT(' Error-THETA larger then sat moisture content(1)')
            NERROR=NERROR+1
         ENDIF
         IF (ATHETA(I).GT.AX(NQ).OR.ATHETA(I).LT.AX(1))THEN
             WRITE(6,1055)
1055         FORMAT(' Error-THETA outside range of curves-(1)')
         ENDIF
51    CONTINUE
      NLAA=NLA+1
      NLH=NLA+NLB
      DO 52 I=NLAA,NLH
         IF(ATHETA(I).GT.ASR2)THEN
            WRITE(6,1060)
1060        FORMAT(' Error-THETA larger than sat moisture content(2)')
            NERROR=NERROR+1
         ENDIF
      IF(ATHETA(I).GT.AX2(NQ).OR.ATHETA(I).LT.AX2(1))THEN
         WRITE(6,1065)
1065     FORMAT(' Error-THETA outside range of curve-(2)')
         NERROR=NERROR+1
      ENDIF
52    CONTINUE
      NLBB=NLB+NLA+1
      DO 53 I=NLBB,NL
         IF(ATHETA(I).GT.ASR3)THEN
            WRITE(6,1070)
1070        FORMAT(' Error-THETA larger than sat moisture content(3)')
            STOP
         ENDIF
```

```
          IF(ATHETA(I).GT.AX3(NQ).OR.ATHETA(I).LT.AX3(1))THEN
             WRITE(6,1075)
 1075        FORMAT(' Error-THETA outside range of curve -(2)')
             NERROR=NERROR+1
          ENDIF
 53    CONTINUE
C
       IF (NERROR.NE.0)THEN
           WRITE(6,1076)NERROR
 1076      FORMAT(' SOILM:   number of input data errors  ',I2,
     &'Simulation terminates')
           STOP
       ENDIF
C
C         DEPTH CALCULATION
C         -----------------
C
C The variable DEPTH is calculated. This refers to the distance from
C ground level to any cell midpoint.
C DIST refers to the distance between any two adjacent cell midpoints.
C
       DIST(1)=TCOM(1)/2.
       DEPTH(1)=DIST(1)
       DO 110 I=2,NL
       DEPTH(I)=DEPTH(I-1)+0.5*(TCOM(I-1)+TCOM(I))
 110   DIST(I)=0.5*(TCOM(I-1)+TCOM(I))
C
C         PARAMETER VARIABILITY
C         ---------------------
C
C  Five input variables, detention capacity, soil water content at
C saturation, soil moisture content at given tensions, saturated conductivity
C and initial moisture content are varied stochastically.
C NAG functions are called which return a 'psuedo random' value from a
C distribution with a given standard deviation and mean.
C All are assumed to have a normal distribution except the saturated
C conductivity which takes on a lognormal.
C
C Generate only one set of stochastic variables to run in MILHY.
C
C         RANDOM PARAMETER VALUE
C         ----------------------
C
       WRITE(6,1079)
 1079    FORMAT(' INCREMENTAL RUNOFF-Parameter variability included'//)
C
C      Detention capacity.
           DETCAP=G05DDF(ADETCAP,SDETCAP)
           IF(DETCAP.LT.0.)DETCAP=0.0
           SD=SDETCAP
           WRITE(6,1180)SD
 1180      FORMAT(' SD of detcap ',F5.3)
C
C      Soil water content at saturation
           SR1=G05DDF(ASR1,SSR1)
           SR2=G05DDF(ASR2,SSR2)
           SR3=G05DDF(ASR3,SSR3)
           SD1=SSR1
```

```
          SD2=SSR2
          SD3=SSR3
          WRITE(6,1181)SD1,SD2,SD3
 1181     FORMAT(' SD of saturated soil content',F5.3,' layer 1'/
     &           '                                ',F5.3,' layer 2'/
     &           '                                ',F5.3,' layer 3')
C
C     Soil moisture content at given tensions
C     Layer 1
        CALL SMCURV(SR1,NQ,AX,Y,XNEW,YNEW,SCURV1)
        DO 120 I=1,20
          X(I)=XNEW(I)
 120      Y(I)=YNEW(I)
C     Layer 2
        CALL SMCURV(SR2,NQ,AX2,Y2,X2NEW,Y2NEW,SCURV2)
        DO 130 I=1,20
          X2(I)=X2NEW(I)
 130      Y2(I)=Y2NEW(I)
C     Layer 3
        CALL SMCURV(SR3,NQ,AX3,Y3,X3NEW,Y3NEW,SCURV3)
        DO 140 I=1,20
          X3(I)=X3NEW(I)
 140      Y3(I)=Y3NEW(I)
        SD1=SCURV1
        SD2=SCURV2
        SD3=SCURV3
        WRITE(6,1182)SD1,SD2,SD3
 1182   FORMAT(' SD of suction moisture curve', F5.3,' layer 1'/
     &         '                                ', F5.3,' layer 2'/
     &         '                                ', F5.3,' layer 3')
C
C Saturated conductivity for each layer
          BSATCON=DLOG10(ASATCON)
          SATCON=G05DDF(BSATCON,SSATCON)
          SATCON=10**SATCON
          BSATCON2=DLOG10(ASATCON2)
          SATCON2=G05DDF(BSATCON2,SSATCON2)
          SATCON2=10**SATCON2
          BSATCON3=DLOG10(ASATCON3)
          SATCON3=G05DDF(BSATCON3,SSATCON3)
          SATCON3=10**SATCON3
          SD1=SSATCON
          SD2=SSATCON2
          SD3=SSATCON3
          WRITE(6,1183)SD1,SD2,SD3
 1183     FORMAT(' SD of sat conductivity',F5.3,' layer 1'/
     &           '                         ', F5.3,' layer 2'/
     &           '                         ', F5.3,' layer 3')
C
C Initial moisture content
          DO 150 I=1,NL
 150          THETA(I)=G05DDF(ATHETA(I),STHETA)
C         Check on initial soil moisture values
          DO 160 I=1,NLA
             IF(THETA(I).GE.X(20))THETA(I)=X(20)-0.001
 160         IF(THETA(I).LE.X(1))THETA(I)=X(1)+0.001
          DO 170 I=NLAA,NLH
             IF(THETA(I).GE.X2(20))THETA(I)=X2(20)-0.001
```

```
170          IF(THETA(I).LE.X2(1))THETA(I)=X2(1)+0.001
            DO 180 I=NLBB,NL
               IF(THETA(I).GE.X3(20))THETA(I)=X3(20)-0.001
180            IF(THETA(I).LE.X3(1))THETA(I)=X3(1)+0.001
          SD=STHETA
           WRITE(6,1184)SD
1184       FORMAT(' SD of initial water content',F5.3)
C
C          HYDRAULIC CONDUCTIVITY CALCULATION
C          ---------------------------------
C
C The hydraulic conductivity is calculated from suction moisture
C data  for each layer.
        NQJ=NQ
        CALL HYDCON(X,SATCON,SR1,Z,Y)
        CALL HYDCON(X2,SATCON2,SR2,Z2,Y2)
        CALL HYDCON(X3,SATCON3,SR3,Z3,Y3)
C
C          WRITE-OUT INITIAL CONDITIONS
C          ----------------------------
C
C Write-out suction moisture curve and generated K-values.
C
        WRITE(6,1080)
1080    FORMAT('OGENERATED K-MOISTURE CURVE'/
       &' Millington-Quirk Method'/
       &' Layer 1',26X,'Layer 2',26X,'Layer 3'/
       &3(' Moisture Suction     Unsat K     '))
        DO 175 I=1,20
175     WRITE(6,1090)X(I),Y(I),Z(I),X2(I),Y2(I),Z2(I),X3(I),Y3(I),Z3(I)
1090    FORMAT(1H ,3(F6.3,2X,F8.3,F15.12,2X))
C Write-out start conditions.
C
        WRITE(6,1100)
1100    FORMAT('OSTART CONDITIONS '/)
        WRITE(6,1110)TIME
1110    FORMAT(' Simulation start time',F4.1,'hrs')
        WRITE(6,1130)ALR,AMR
1130    FORMAT(' Precipitation begins at ',F4.1,2X,'and ends at ',F4.1)
        WRITE(6,1140)DT
1140    FORMAT(' Rainfall data time increment = ',F6.4,2X,'hrs')
        WRITE(6,1120)AF
1120    FORMAT(' Time increment for iteration period = ',F6.1,
       &2X,'secs'/)
        WRITE(6,1150)EMAX,DETCAP
1150    FORMAT(' Maximum evaporation during the day = ',F10.8,2X,'ms-1'/
       &' Surface detention capacity = ',F6.4,2X,'m'//)
C
C Calculate initial relative saturation of each cell in soil column
        DO 1151 I=1,NL
           IF(I.LE.NLA)RSAT(I)=THETA(I)/SR1
           IF(I.GT.NLA.AND.I.LT.NLBB)RSAT(I)=THETA(I)/SR2
           IF(I.GE.NLBB)RSAT(I)=THETA(I)/SR3
1151    CONTINUE
        WRITE(6,1152)
1152    FORMAT(' INITIAL SOIL COLUMN CONDITIONS'//)
        WRITE(6,1153)
1153    FORMAT(11X,'SAT',8X,'SAT HYD',6X,'CELL',1X,'DEPTH',
```

```
      &2X,'INITAL',2X,'REL'/
      &1H ,10X,'THETA',7X,'COND',9X,'NO',10X,'THETA',2X,'SAT'/
      &1H ,10X,'m3/m3',7X,'ms-1',14X,'m',5X,'m3/m3'/)
       WRITE(6,1154)SR1,SATCON,DEPTH(1),THETA(1),RSAT(1)
 1154  FORMAT(' Layer 1  ',F7.4,1X,F15.12,3X,'1',2X,F6.4,1X,F7.4,1X,F5.3)
       IF(NLA.GT.1)THEN
           DO 1155 I=2,NLA
               WRITE(6,1156)I,DEPTH(I),THETA(I),RSAT(I)
 1156          FORMAT(1H ,34X,I2,2X,F6.4,1X,F7.4,1X,F5.3)
 1155      CONTINUE
       ENDIF
       WRITE(6,1157)SR2,SATCON2,NLAA,DEPTH(NLAA),THETA(NLAA),RSAT(NLAA)
 1157  FORMAT(' Layer 2  ',F7.4,1X,F15.12,2X,I2,2X,F6.4,1X,F7.4,1X,F5.3)
       IF(NLB.GT.1)THEN
           DO 1158 I=NLA+2,NLH
               WRITE(6,1159)I,DEPTH(I),THETA(I),RSAT(I)
 1159          FORMAT(1H ,34X,I2,2X,F6.4,1X,F7.4,1X,F5.3)
 1158      CONTINUE
       ENDIF
       WRITE(6,1160)SR3,SATCON3,NLH+1,DEPTH(NLH+1),THETA(NLH+1),
      &RSAT(NLH+1)
 1160  FORMAT(' Layer 3  ',F7.4,1X,F15.12,2X,I2,2X,F6.4,1X,F7.4,1X,F5.3)
       IF((NL-NLH).GT.1)THEN
           DO 1161 I=NLH+2,NL
               WRITE(6,1162)I,DEPTH(I),THETA(I),RSAT(I)
 1162          FORMAT(1H ,34X,I2,2X,F6.4,1X,F7.4,1X,F5.3)
 1161      CONTINUE
       ENDIF
C
C         INITIALISATION OF VARIABLES
C         ---------------------------
C
         DO 184 I=1,300
 184     IWWW=W
         WDATA(I,IWWW)=0.0
       WATI=0.0
       MMM=2
         DO 185 I=2,NL
 185     ANFLUX(I)=0.0
       CTIME=TIME*3600
       SRAIN1=0.0
       CUMDRN=0.
       CINFIL=0.
       SUMD=0.
       ICOUNT =0
       BR=AMR-ALR
       EVAPI=0.0
       SOG=THETA(1)/SR1
       RTOT=0.0
       ANFILT=0.0
       PPTT=0.0
       TG=0.0
C
C        BALANCE CHECK
C        -------------
C
C A calculation for the water balance check.
C The initial soil water content of the soil column.
```

```
C
      DO 190 I=1,NL
190   WATI=TCOM(I)*THETA(I)+WATI
C
C         CURVE GRADIENTS
C         ---------------
C
C Calculations of the gradients of the suction-moisture curve and the
C K-moisture curve for each layer.
C
      CALL GRAD(G,GZ,Y,X,Z)
      CALL GRAD(G2,GZ2,Y2,X2,Z2)
      CALL GRAD(G3,GZ3,Y3,X3,Z3)
C
C
C         ---------------------------
C         DYNAMIC SECTION - SIMULATION
C         ---------------------------
C
C
C This loop is completed for each time increment until end of simulation.
C
      ITMAX=SIMDUR*3600/AF
        DO 9995 II=1,ITMAX
      ICOUNT=ICOUNT+AF
      TG=TG+AF
      T=II
C
C         CALCULATE WATER VOLUME OF EACH CELL
C         ----------------------------------
C
      DO 200 I=1,NL
200   VOL(I)=TCOM(I)*THETA(I)
C
C         24-HOUR CLOCK
C         -------------
C
C Calculate REAL TIME for current iteration period using the 24-hour clock
C
      CTIME=CTIME+AF
      IF (CTIME.GE.86400)THEN
         CTIME=CTIME-86400
      ENDIF
C
C         SWP,HPOT,COND CALCULATIONS
C         -------------------------
C
C Calculate the soil water pressure, hydraulic potential and conductivity
C for each cell as conditions change during the simulation.
C
      CALL TWO(1,NLA,THETA,X,SWP,Y,G,HPOT,DEPTH,GZ,COND,Z)
      CALL TWO(NLAA,NLB,THETA,X2,SWP,Y2,G2,HPOT,DEPTH,GZ2,COND,Z2)
      CALL TWO(NLBB,NL,THETA,X3,SWP,Y3,G3,HPOT,DEPTH,GZ3,COND,Z3)
C
C         DETERMINE RAINFALL
C         -----------------
C
C Determine rainfall per second at end of the current iteration
```

```
C period.
C T1 is the time in hours when the current iteration period ends.
C Check that T1 is between the rain start and stop.
C If it is, decide which element of PPT array the data is to be taken from
C and make SRAIN equal to that precipitation per second.
C If it is not within the storm period, set SRAIN to 0.
C
C
      T1=T*AF/3600.0
      IF(T1.LE.(ALR-TIME).OR.T1.GT.(AMR-TIME))THEN
       SRAIN=0.0
      ELSE
       T2=T1-(AF/3600.)
       IELEM=((T2-(ALR-TIME))/DT)+1
       SRAIN=PPT(IELEM)/(DT*3600.0)
      ENDIF
c
C Increment precipitation total by amount of precipitation in current
C iteration period.
C
      PPTT=PPTT+(SRAIN*AF)
C
C         AVERAGE HYDRAULIC CONDUCTIVITY
C         ------------------------------
C
C Average hyraulic conductivity for flow through boundary between
C adjoining cells is weighted according to its thickness.
C
        DO 210 I=2,NL
210    AVCOND(I)=(COND(I-1)*TCOM(I-1)+COND(I)*TCOM(I))
     &/(TCOM(I-1)+TCOM(I))
C
C         BOTTOM BOUNDARY CONDITION
C         -------------------------
C
C Determine the bottom boundary condition under the assumption that
C water is flowing out of the soil column under gravity.
C
      FLUX(NLL)=COND(NL)
C
C         FLUX BETWEEN CELLS
C         ------------------
C
C The flux between each cell then follows Darcy's law in discrete form.
C
      DO 220 I=2,NL
220   FLUX(I)=(HPOT(I-1)-HPOT(I))*AVCOND(I)/DIST(I)
C
C         DETERMINE TOP BOUNDARY CONDITIONS
C         ---------------------------------
C
C Calculate the infiltration capacity.
C
      BNCAP=(0.0-HPOT(1))*0.5*(SATCON+COND(1))/DIST(1)
C
C Calculate precipitation excess
C
      IF(SRAIN1.EQ.SRAIN)THEN
```

```
         SUMD=(SRAIN-ANFILT)*AF+SUMD
       ELSE
          SUMD=0.0+SUMD
       ENDIF
       SRAIN1=SRAIN
C
C Calculate amount detained on the surface.
C
       IF(SUMD.LT.0.0)THEN
          DETAIN=0.0
       ELSE
          DETAIN=SUMD
       ENDIF
C
C Calculate evaporation, the flux into cell 1 and runoff.
C
       IF(SRAIN.GT.0.0) THEN
C
        EVAP= 0.0
C
        IF(SRAIN.LT.BNCAP.AND.DETAIN.LE.0.0)THEN
           ANFILT=SRAIN
        ELSE
           ANFILT=BNCAP
        ENDIF
        FLUX(1)=ANFILT
C
        IF(DETAIN.GT.DETCAP)THEN
          SUMD=DETCAP
          DETAIN=DETCAP
          RUNOFF=0.0
          IF(SRAIN.GT.BNCAP)RUNOFF=(SRAIN-BNCAP)*AF
          RTOT=RTOT+RUNOFF
        ELSE
          RUNOFF=0.0
        ENDIF
C
       ELSE
C
        RUNOFF=0.0
C       CORRECTED VERSION MILHY3
         IF(CTIME.GT.64800.OR.CTIME.LE.21600)THEN
            EVAP=EMAX/100.
        ELSE
            EVAP=EMAX*SIN(2.*3.14159*(CTIME-21600.)/86400.)
        ENDIF
C
        IF(DETAIN.LE.0.)THEN
            ANFILT=0.0
            FLUX(1)=EVAP*(-1.)
        ELSE
            ANFILT=BNCAP
            FLUX(1)=ANFILT
              DETAIN=DETAIN-(EVAP*AF)
        ENDIF
C
       ENDIF
C
```

```
C        CHANGES IN SOIL MOISTURE CONTENT
C        -------------------------------
C
      SWP(NLL)=-102.0
      DO 230 I=1,NL
C     If SWP in cell is greater then 0, it is saturated and flux must
C     therefore be 0.
      IF(SWP(I+1).GE.0.0)FLUX(I+1)=0.0
C     ANFLUX represents the net change in moisture content in the cell.
      ANFLUX(I)=FLUX(I)-FLUX(I+1)
      ANFLUX(I)=ANFLUX(I)*AF
C     Recalculate theta according to the  change influx(per unit area).
      THETA(I)=(VOL(I)+ANFLUX(I))/TCOM(I)
C     Due to recalculation, theta may be greater than possible water content
C     at saturation and therefore it is necessary to reset SWP to
C     0 and theta to the water content at saturation, the value of which is
C     entered into the model.
      IF (THETA(I).GE.SR1.AND.I.LE.NLA)SWP(I)=0.0
      IF (THETA(I).GE.SR2.AND.I.GT.NLA.AND.I.LE.NLH)SWP(I)=0.0
      IF(THETA(I).GE.SR3.AND.I.GT.NLH)SWP(I)=0.0
      IF(THETA(I).GE.SR1.AND.I.LE.NLA)THETA(I)=SR1
      IF(THETA(I).GE.SR2.AND.I.GT.NLA.AND.I.LE.NLH)THETA(I)=SR2
230   IF(THETA(I).GE.SR3.AND.I.GT.NLB)THETA(I)=SR3
C
C        CALCULATE CUMULATIVE TOTALS
C        --------------------------
C
      CUMDRN=CUMDRN+FLUX(NLL)*AF
      EVAPI=EVAP*AF+EVAPI
      CINFIL=CINFIL+ANFILT*AF
      SOG=THETA(1)/SR1
C
C
C        --------------------------
C        TERMINAL SECTION  WRITE OUT
C        --------------------------
C
C
C To print out data for every time increment for which PPT data is
C entered, check ICOUNT to see if that period has passed by.
      IF(ICOUNT.LT.(DT*3600)) GOTO 9995
      ICOUNT=0
C
C        CALCULATE TIME FROM THE START
C        ----------------------------
C
      T=T*AF/3600
      WRITE(6,1170)T
1170  FORMAT('0SOIL COLUMN CONDITIONS ',F7.3,1X,'HRS SINCE
     & SIMULATION BEGAN'/)
      IF(TG.EQ.86400.0)TG=0.0
C
C        WRITE-OUT CONDITIONS OF SOIL COLUMN
C        -----------------------------------
C
      IF(IOUT.EQ.0)GOTO 305

      WRITE(6,7780)
```

```
7780 FORMAT(' Cell  Depth    SWP    Theta     Hyd cond     Net',1X,
    &'flux     Rel sat')
       DO 300 I=1,NL
       IF(I.LE.NLA)SOG=THETA(I)/SR1
       IF(I.GT.NLA.AND.I.LT.NLBB)SOG=THETA(I)/SR2
       IF(I.GE.NLBB)SOG=THETA(I)/SR3
300    WRITE(6,1190)I,DEPTH(I),SWP(I),THETA(I),COND(I),ANFLUX(I),SOG
1190 FORMAT(I6,3F8.4,2F14.9,F9.3)
C
C        WATER BALANCE CHECK
C        ------------------
C
C Philips (1964) simple water balance;
C -------
C
C                                    Amount added
C    (Initial soil)-(Current soil) =      by       - Evaporation- Drainage
C    (  moisture   ) (  moisture   )  infiltration       loss        loss
C
305  WATN=0.
       DO 310 I=1,NL
310    WATN=TCOM(I)*THETA(I)+WATN
     BAL=WATN-WATI-CINFIL+EVAPI+CUMDRN
     WRITE(6,1200)BAL
1200 FORMAT('0Balance check on soil column water status =',F12.7)
     BAL=(BAL*100.)/WATN
     WRITE(6,1210)BAL
1210 FORMAT(' Balance check as  column water vol.   =',F12.7,' %'/)
C
C
     IF(IOUT.EQ.0)GOTO 306

     WRITE(6,1220)EVAPI,PPTT,CINFIL,CUMDRN
1220  FORMAT(' Cumulative evaporation   = ',F12.8/
    &' Cumulative precipitation = ',F8.4/
    &' Cumulative infiltration  = ',F10.6/
    &' Cumulative drainage      = ',F10.6/)
306  IF(DETAIN.EQ.DETCAP)THEN
        WRITE(6,1222)
1222    FORMAT(' Detention capacity exceeded')
        WRITE(6,1230)RTOT,RTOT/.0254,T
1230    FORMAT(' Runoff total in the last period',F10.7,2X,'m'/
    &    ' Runoff total in the last period',F10.7,2X,'ins',
    $      F7.3/)
     ELSE
        WRITE(6,1221)DETAIN
1221    FORMAT(' Surface water = ',F10.6)
        WRITE(6,1226)
1226    FORMAT(' No runoff')
     ENDIF
C
C        CREATION OF ARRAY DATA
C        ---------------------
C
C Runoff is recorded in array WDATA
C The runoff for each soil column is weighted according to the
C percentage area which it occupies in the catchment area
     IWWW=W
```

```
      WDATA(MMM,IWWW)=(RTOT/.0254)*(IPCAREA/100.)
      RTOT=0.0
      MMM=MMM+1
9995  CONTINUE
C
C End of simulation of single soil column, it more than one, then return to
C to the beginning of this subroutine to repeat for next soil column
C
34543  CONTINUE
      DO 76567 I=1,MMM
C     Sum the weighted runoff for each soil column to derive total runoff
C     passed back to CMPHYD as DATA
         CUMDATA=0.
         DO 54345 J=1,NSCOL
              CUMDATA=WDATA(I,J)+CUMDATA
54345   CONTINUE
        DATA(I)=CUMDATA
76567 CONTINUE
      IR=MMM-1
C
      RETURN
      END
C
C
C ========================================
C
      SUBROUTINE HYDCON(X,SATCON,SR,Z,Y)
C
C ========================================
C
C This subroutine calculates hydraulic conductivity for each layer
C from the given soil moisture characteristic curve.
C Uses the Millington and Quirk method
C
      DIMENSION X(20),Y(20),Z(20)
      DO 845 I=1,20
      IIJ=20-I+1
      XII=X(IIJ)
      TOPS=0.
      BOTS=0.
         DO 846 J=1,20
         JF=20-J+1
         YJJ=Y(JF)
 846     BOTS=((2*J-1)*YJJ**(-2))+BOTS
      II=I
         DO 847 J=II,20
         JF=20-J+1
         YJJ=Y(JF)
  847    TOPS=((2*J+1-2*I)*YJJ**(-2))+TOPS
      JT=20-I+1
  845 Z(JT)=SATCON*(X(II)/SR)*TOPS/BOTS
      RETURN
      END
C
C
C ========================================
C
      SUBROUTINE TWO(NA,NB,THETA,X,SWP,Y,G,HPOT,DEPTH,GZ,COND,Z)
```

```
C
C ==============================================
C
C This subroutine calculates soil water pressure, hydraulic potential
C and hydraulic conductivity for each cell as conditions change
C during simulation.

      DIMENSION THETA(20),X(20),SWP(20),Y(20),G(20),HPOT(20),
     &DEPTH(20),GZ(20),COND(20),Z(20)
      DO 15 I=NA,NB
         DO 16 J=1,19
         IF(THETA(I).GE.X(J).AND.THETA(I).LT.X(J+1))SWP(I)=Y(J)+G(J)*
     &   (THETA(I)-X(J))
 16      CONTINUE
      HPOT(I)=SWP(I)-DEPTH(I)
         DO 17 J=1,19
         IF(THETA(I).GT.X(J).AND.THETA(I).LE.X(J+1))COND(I)=Z(J)+GZ(J)*
     &   (THETA(I)-X(J))
 17      CONTINUE
 15   CONTINUE
        RETURN
        END
C
C
C ==============================================
C
      SUBROUTINE GRAD(G,GZ,Y,X,Z)
C
C ==============================================
C
C This subroutine calculates the gradients of the suction-moisture
C and hydraulic conductivity-moisture curves.
C
      DIMENSION G(20),GZ(20),Y(20),X(20),Z(20)
      DO 261 I=1,19
      G(I)=(Y(I+1)-Y(I))/(X(I+1)-X(I))
261   GZ(I)=(Z(I+1)-Z(I))/(X(I+1)-X(I))
      RETURN
      END
C
C
C ==============================================
C
      SUBROUTINE SMCURV(SR,NQ,AX,Y,XNEW,YNEW,SCURV)
C
C ==============================================
C
C  Generates a stochastic suction moisture curve to be fed into
C  soil moisture model
C
      DOUBLE PRECISION G05DDF
      DOUBLE PRECISION AX,SCURV
      DIMENSION AX(20),X(20),XNEW(20),YNEW(20),G(20),Y(20)
C
C  Determine the stochastic values of moisture
C
      X(1)=G05DDF(AX(1),SCURV)
      IF(X(1).LT.0.)X(1)=0.001
```

```
C
      DO 100 I=2,NQ
      X(I)=G05DDF(AX(I),SCURV)
100   IF(X(I).LE.X(I-1))X(I)=X(I-1)+0.001
      IF(X(NQ).GE.SR)SR=X(NQ)+0.001
C
C Calculate gradients of this new suction-moisture curve
c
      NNQ=NQ-1
      DO 200 I=1,NNQ
200   G(I)=(Y(I+1)-Y(I))/(X(I+1)-X(I))
C
C Calculate max and min moisture values, and determine the size of
C equal intervals.
C
      XMAX=RMAX(X,NQ)
      XMIN=RMIN(X,NQ)
      XINT=(XMAX-XMIN)/19.
C
C Determine the new values of moisture-equal intervals
C
      XNEW(1)=XMIN
      DO 300 I=2,19
300   XNEW(I)=XNEW(1)+(XINT*(I-1))
      XNEW(20)=XMAX
C
C Determine the associated new values of suction
C
      DO 350 I=1,19
        DO 400 J=1,NNQ
          IF(XNEW(I).GE.X(J).AND.XNEW(I).LT.X(J+1))
     &    YNEW(I)=Y(J)+G(J)*(XNEW(I)-X(J))
400     CONTINUE
350   CONTINUE
      YNEW(20)=Y(NQ)
C
      RETURN
      END
C
C
C ==========================================
C
      FUNCTION RMAX (X,NQ)
C
C ==========================================
C
C Determines the maximum real in an array
C
      DIMENSION X(NQ)
      RMAX=X(1)
      DO 10 I=2,NQ
10    IF(X(I).GT.RMAX)RMAX=X(I)
C
      RETURN
      END
C
C
C ==========================================
```

```

      FUNCTION RMIN(X,NQ)
C
C ==========================================
C
C Determines minimum real in an array
      DIMENSION X(NQ)
      RMIN=X(1)
      DO 10 I=2,NQ
10    IF(X(I).LT.RMIN)RMIN=X(I)
C
      RETURN
      END
C
C
C ==========================================
C
      SUBROUTINE PRTHYD
C
C ==========================================
C
C     THIS SUBROUTINE PRINTS THE CORRDINATES OF A HYDROGRAPH
C     CONVERTS Q HYDROGRAPH TO STAGE HYDROGRAPH FOR SPECIFIED X-SECTION
C
C     ID=Q HYD INPUT
C     IDR=CROSS SECTION ID
C     HYDROGRAPH FORM
C       NPK=2 OR GREATOR FOR CONVERSION Q/STAGE
C       NPK=1 Q HYD
C       NPK=0 Q PEAK AND VOLUME ONLY
C     IN = FORMAT OF OUTPUT
C       IN =0  REGULAR FORMAT
C       IN=1 PRINT DISCHARGE ONLY IN SINGLE ENTRY PER LINE
C
      COMMON/BLOCK2/OCFS(300,6),DATA(310),RAIN(300),ROIN(6),
     &IEND(6),DA(6),DT(6),PEAK(6),TIME,KCODE,ICODE
C
      COMMON/BLOCK3/A(20,70),Q(20,70),DEEP(20,70),DP(20),
     &SCFS(20),C(20,6),DIST(6),SEGN(6),ISG(6),PERQ(20,70),
     &TQ(20,6),CC(20),LL(6),INRC,LRC
C
      DIMENSION DUMMY(300),S(300,6),PEAKS
      DIMENSION ISG(6)
C  New variables used
C  S  stage equivalent of OCFS
C  PEAKS peak stage (equivalent of PEAK)
C
      ID=DATA(1)
      NPK=DATA(2)
      IDR=DATA(3)
      IN=DATA(4)
      M=IEND(ID)
      WRITE(6,40)ID,NPK
      TIME1=0
      IF(NPK.LT.1)GOTO 32
      IF(NPK.LT.2)GOTO 2
C     CONVERSION TO STAGE HYDROGRAPH
C     CHECK RATING CURVE ENTERED
```

```
      IF(IDR.EQ.0)THEN
      WRITE(6,*)'NEED TO ENTER RATING CURVE ID'
      RETURN
      ENDIF
C     Checkk if segment or cross-section
      IF(IDR.GT.6) GOTO 51
C     Check if multiple routing invoked
      IF(TQ(20,IDR).GT.0)THEN
      DO 50 I=1,20
50    Q(I,IDR)=TQ(I,IDR)
      ENDIF
      JJ=IDR
      GOTO 7
C     Use segment to convert
51    JJ=IDR/10
7     DO 3 I=1,M
      J=1
6     IF(OCFS(I,ID).LE.Q(J,IDR))GOTO 4
      J=J+1
      IF(J.GT.20)THEN
      WRITE(6,*)'RATING CURVE EXCEEDED, STOPPED'
      RETURN
      ENDIF
      GOTO 6
4     IF(OCFS(I,ID).EQ.Q(J,IDR))THEN
      S(I,ID)=C(J,JJ)
      GOTO 3
      ENDIF
C     INTERPOLATE
      S(I,ID)=C(J,JJ)-((C(J,JJ)-C(J-1,JJ))*(Q(J,IDR)-OCFS(I,ID))/
     &(Q(J,IDR)-Q(J-1,IDR)))
3     CONTINUE
C     TIME ARRAY
2     DO 8 I=1,M
      DATA(I)=TIME1
8     TIME1=TIME1+DT(ID)
      J=0
      M4=M+4
      M5=M4/5
      IF(NPK.LT.2)GOTO 27
      IF(ICODE.EQ.0)THEN
      WRITE(6,9)
      GOTO 10
      ENDIF
      WRITE(6,11)
10    IF(IN.GT.0)THEN
      IF(ICODE.EQ.0)THEN
      DO 38 I=1,M
38    WRITE(6,28)S(I,ID)
      RETURN
      ENDIF
      DO 43 I=1,M
      S(I,ID)=S(I,ID)*0.3048
43    WRITE(6,28)S(I,ID)
      RETURN
      ENDIF
      IF(ICODE.GT.0)THEN
      DO 45 I=1,M
```

```
45    S(I,ID)=S(I,ID)*0.3048
      ENDIF
39    J=J+1
      WRITE(6,30)(DATA(I),S(I,ID),I=J,M,M5)
      IF(J-M5)39,13,13
13    ROIN1=ROIN(ID)
      DO 16 I=1,20
      IF(Q(I.IDR)-PEAK(ID))16,17,17
16    CONTINUE
17    IF(Q(I,IDR).EQ.PEAK(ID))THEN
      PEAKS=C(I,JJ)
      GOTO 18
      ENDIF
      PEAKS=C(I,JJ)-((C(I,JJ)-C(I-1,JJ))*(Q(I,IDR)-PEAK(ID))/
     &(Q(I,IDR)-Q(I-1,IDR)))
18    IF(ICODE.EQ.0)THEN
      WRITE(6,14)ROIN1,PEAKS
      RETURN
      ENDIF
      PEAKS=PEAKS*0.3048
      ROIN1=ROIN(ID)*0.0283168
      WRITE(6,15)ROIN1,PEAKS
      RETURN
C     DISCHARGE HYDROGRAPHS
27    IF(ICODE.EQ.1)THEN
C     METRIC
      WRITE(6,21)
      DO 23 I=1,M
23    DUMMY(I)=OCFS(I,ID)*0.0283168
      PEAK1=PEAK(ID)*0.0283168
      ROIN1=ROIN(ID)*0.0283168
      GOTO 20
      ENDIF
C     IMPERIAL
19    WRITE(6,25)
      DO 26 I=1,M
26    DUMMY(I)=OCFS(I,ID)
      PEAK1=PEAK(ID)
      ROIN1=ROIN(ID)
20    IF(IN.GT.0)THEN
      DO 29 I=1,M
29    WRITE(6,28)DUMMY(I)
      RETURN
      ENDIF
31    J=J+1
      WRITE(6,30)(DATA(I),DUMMY(I),I=J,M,M5)
      IF(J-M5)31,32,32
32    IF(ICODE.NE.0)GOTO 34
      ROIN1=ROIN(ID)
      PEAK1=PEAK(ID)
      WRITE(6,35)ROIN1,PEAK1
      RETURN
34    ROIN1=ROIN(ID)*0.0283168
      PEAK1=PEAK(ID)*0.0283168
      WRITE(6,36)ROIN1,PEAK1
      RETURN

21    FORMAT(10X,"TIME",6X," FLOW",11X,"TIME",6X," FLOW",11X,"TIME",
```

```
     &6X,"FLOW",11X,"TIME",6X,"FLOW",11X,"TIME",6X,"FLOW"/11X,"HRS",
     &7X," MS",12X,"HRS",7X," MS",12X,"HRS",7X," MS",12X,"HRS",
     &7X," MS",12X,"HRS",7X," MS")
25    FORMAT(10X,"TIME",6X," FLOW",11X,"TIME",6X," FLOW",11X,"TIME",
     &6X,"FLOW",11X,"TIME",6X,"FLOW",11X,"TIME",6X,"FLOW"/11X,"HRS",
     &7X," CFS ",10X,"HRS",7X," CFS ",10X,"HRS",7X," CFS ",10X,"HRS",
     &7X," CFS ",10X,"HRS",7X," CFS ")
30    FORMAT (5(5X,F10.3,F10.3))
40    FORMAT(   'PRINT HYD',T21,'ID=',I1,T29,'NPK=',I1)
36    FORMAT(1H0,9X,"HYDROGRAPH VOLUME=",F20.0," CUMEC  "/10X,"PEAK
     &DISCHARGE RATE =",F10.0,"CMS"///)
35    FORMAT(1H0,9X,"HYDROGRAPH VOLUME=",F20.0," CF  "/10X,"PEAK
     &DISCHARGE  RATE=",F10.0,"CFS"///)
14    FORMAT(1H0,9X,"HYDROGRAPH VOLUME=",F20.0," CF  "/10X,"PEAK
     &ELEVATION      =",F10.0," FEET"///)
15    FORMAT(1H0,9X,"HYDROGRAPH VOLUME=",F20.0,"CUMECS"/10X,"PEAK
     &ELEVATION       =",F10.0,"METRES"///)
11    FORMAT(10X,"TIME",6X,"ELEV",11X,"TIME",6X,"ELEV",11X,"TIME",
     & 6X,"ELEV",11X,"TIME",6X,"ELEV",11X,"TIME",6X,"ELEV",/11X,"HRS",
     & 7X,"M ",12X,"HRS",7X,"M ",12X,"HRS",7X,"M ",12X,"HRS",
     & 7X,"M ",12X,"HRS",7X,"M ")
9     FORMAT(10X,"TIME",6X,"ELEV",11X,"TIME",6X,"ELEV",11X,"TIME",
     & 6X,"ELEV",11X,"TIME",6X,"ELEV",11X,"TIME",6X,"ELEV",/11X,"HRS",
     & 7X,"FT",12X,"HRS",7X,"FT",12X,"HRS",7X,"FT",12X,"HRS",
     & 7X,"FT",12X,"HRS",7X,"FT")
28    FORMAT(F10.3)
      END
C
C
C ===========================================
C
      SUBROUTINE HPLOT
C
C ===========================================
C
C     THIS SUBROUTINE PLOTS EITHER 1 OR 2 HYDROGRAPHS ON A SET OF AXIS
C
      COMMON/BLOCK2/OCFS(300,6),DATA(310),RAIN(300),ROIN(6),
     &IEND(6),DA(6),DT(6),PEAK(6),TIME,KCODE,ICODE
C
      DIMENSION CFS(300)
      ID1=DATA(1)
      ID2=DATA(2)
      DATA ZERO, PLUS, BLANK, DASH, DOT/'0','+',' ','-','.'/
      MAX=121
      J=1
C     ARE THERE 1 OR 2 HYDROGRAPHS
      IF (ID2) 1,1,2
C     DETERMINE HIGHEST PEAK IF 2 HYDROGRAPHS
1     QMAX=PEAK(ID1)
      GO TO 14
2     IF (PEAK(ID1)-PEAK(ID2)) 3,3,4
3     QMAX=PEAK(ID2)
      GO TO 5
4     QMAX=PEAK(ID1)
C     IF 2 HYDROGRAPHS DETERMINE LARGEST DT AND INTERPOLATE OTHER
C     HYDROGRAPH IF NECESSARY
5     IF (DT(ID1)-DT(ID2)) 6,13,7
```

```
6     L=ID1
      K=ID2
      GO TO 8
7     L=ID2
      K=ID1
8     M=IEND(L)
      TID=DT(K)
      TIDH=0.
      DO 11 I=2,M
      TIDH=TIDH+DT(L)
      IF (TID-TIDH) 10,9,11
9     J=J+1
      CFS(J)=OCFS(I,L)
      TID=TID+DT(K)
      GO TO 11
10    J=J+1
      CFS(J)=OCFS(I-1,L)+((TID-TIDH+DT(L))/DT(L))*(OCFS(I,L)-OCFS(I-1,L)
     &)
      TID=TID+DT(K)
11    CONTINUE
      IEND(L)=J
      DT(L)=DT(K)
      DO 12 I=2,J
12    OCFS(I,L)=CFS(I)
13    IF (IEND(ID1)-IEND(ID2)) 14,14,15
14    M=IEND(ID1)
      GO TO 16
15    M=IEND(ID2)
16    XM = M
C     DETERMINE TIME SCALE
      XSCL = XM / 120.
      YSCL=QMAX/50.
C     PLOT HYDROGRAPHS
      DO 20 I=1,MAX
20    CFS(I)=DASH
      IF(ICODE.EQ.0)GO TO 49
      WRITE(6,50)
50    FORMAT(T2,"FLOW RATE (CMS)")
      QMAX1=QMAX*0.02832
      WRITE(6,41)QMAX1,DOT,(CFS(I),I=1,MAX),DOT
      GO TO 51
49    WRITE(6,48)
48    FORMAT(T2,'FLOW RATE (CFS)')
      WRITE(6,41)QMAX,DOT,(CFS(I),I=1,MAX),DOT
51    Q1=QMAX
      J1=10
      DO 37 J=1,50
      IF (J-J1) 23,21,23
21    DO 22 I=1,MAX
22    CFS(I)=DASH
      GO TO 25
23    DO 24 I=1,MAX
24    CFS(I)=BLANK
25    Q2=Q1-YSCL
      DO 28 I=2,M
      IF (OCFS(I,ID1)-Q1) 26,27,28
26    IF (OCFS(I,ID1)-Q2) 28,28,27
27    XI = I
```

```
       K = XI / XSCL + 1.
       CFS(K)=ZERO
 28    CONTINUE
       WRITE (6,44) DOT,(CFS(I),I=1,MAX),DOT
       IF (ID2) 34,34,29
 29    DO 18 I = 1, MAX
 18    CFS(I) = BLANK
       DO 33 I=1,M
       IF (OCFS(I,ID2)-Q1) 30,31,33
 30    IF (OCFS(I,ID2)-Q2) 33,33,31
 31    XI = I
       K = XI / XSCL + 1.
       CFS(K)=PLUS
 33    CONTINUE
       WRITE (6,42) (CFS(I),I=1,MAX)
 34    IF (J-J1) 36,35,36
 35    J1=J1+10
       IF(ICODE.EQ.0)GO TO 52
       QD=Q2*0.02832
       WRITE(6,43)QD
       GO TO 36
 52    WRITE(6,43)Q2
 36    Q1=Q2
 37    CONTINUE
       CFS(1)=TIME
       DTT=DT(ID1)*(XM - 1.) / 12.
 C     PUT TIME ARRAY IN CFS AND WRITE TIME SCALE
       DO 38 I=2,13
 38    CFS(I)=CFS(I-1)+DTT
       WRITE (6,45) (CFS(I),I=1,13)
       WRITE (6,46)
       RETURN
 C
 41    FORMAT(1X,F7.0,123A1)
 42    FORMAT(1H+,8X,121A1)
 43    FORMAT (1H+,F7.0)
 44    FORMAT(8X,123A1)
 45    FORMAT(T3,13F10.2)
 46    FORMAT(49X,'TIME HOURS'///)
       END
 C
 C
 C ---------------------------------------------
 C
       SUBROUTINE ADHYD
 C
 C ---------------------------------------------
 C
 C     THIS SUBROUTINE ADDS TWO HYDROGRAPHS.
 C
       COMMON/BLOCK2/OCFS(300,6),DATA(310),RAIN(300),ROIN(6),
      &IEND(6),DA(6),DT(6),PEAK(6),TIME,KCODE,ICODE

       ID=DATA(1)
       NHD=DATA(2)
       ID1=DATA(3)
       ID2=DATA(4)
       KK=0
```

```
C     CHECK ARRAYS ARE NOT EMPTY
      IF(IEND(ID1).EQ.0.OR.IEND(ID2).EQ.0)THEN
      WRITE(6,101)
      IF(IEND(ID1).EQ.0)THEN
      K=ID2
      GOTO 29
      ENDIF
      K=ID1
29    DO 30 I=1,IEND(K)
30    OCFS(I,ID)=OCFS(I,K)
      PEAK(ID)=PEAK(K)
      ROIN(ID)=ROIN(K)
      DA(ID)=DA(K)
      IEND(ID)=IEND(K)
      DT(ID)=DT(K)
      GOTO 27
      ENDIF
      IF(DT(ID1).EQ.DT(ID2))GOTO 31
      IF(ID.NE.ID1.AND.ID.NE.ID2)GOTO 31
C     DANGER OF CONFUSION IN DT, ALTER ID TO KK
32    DO 33 KK=1,6
      IF(KK.EQ.ID1)GOTO 33
      IF(KK.EQ.ID2)GOTO 33
      GOTO 34
33    CONTINUE
34    ID=KK
31    PEAK(ID) = 1.
C     MAKE TIME INCREMENTS EQUAL IF NOT EQUAL. USE SMALLER INCREMENT
      IF (DT(ID1)-DT(ID2)) 1,3,2
1     DT(ID)=DT(ID1)
      L=ID1
      K=ID2
      GO TO 6
2     DT(ID)=DT(ID2)
      L=ID2
      K=ID1
      GO TO 6
3     DT(ID)=DT(ID1)
      IF (IEND(ID1)-IEND(ID2)) 4,4,5
4     M3=IEND(ID1)
      K1=ID2
      IEND(ID)=IEND(ID2)
      GO TO 18
5     M3=IEND(ID2)
      K1=ID1
      IEND(ID)=IEND(ID1)
      GO TO 18
C     DETERMINE DURATIONS OF FLOW
6     XIEND1=IEND(ID1)-1
      XIEND2=IEND(ID2)-1
      DUR1=XIEND1*DT(ID1)
      DUR2=XIEND2*DT(ID2)
      IF (DUR1-DUR2) 7,8,8
7     IEND(ID)=DUR2/DT(ID)+1.
      M3=DUR1/DT(ID)+1.
      K1=ID2
      GO TO 9
8     IEND(ID)=DUR1/DT(ID)+1.
```

```
      M3=DUR2/DT(ID)+1.
      K1=ID1
 9    IF (IEND(ID)-300) 11,11,10
 10   IEND(ID)=300
 11   M2=IEND(K)
      J=1
C     INTERPOLATE ONE HYDROGRAPH IF NECESSARY
      TIDH=0.
      TID=DT(ID)
      DO 15 I=2,M2
      TIDH=TIDH+DT(K)
 12   IF (TIDH-TID) 15,13,14
 13   J=J+1
      DATA (J)=OCFS(I,K)
      TID=TID+DT(ID)
      IF (J-300) 15,16,16
 14   J=J+1
      DATA (J)=OCFS(I-1,K)+((TID-TIDH+DT(K))/DT(K))*(OCFS(I,K)-OCFS(I-1,
     &K))
      TID=TID+DT(ID)
      IF (J-300) 12,16,16
 15   CONTINUE
 16   IEND(K)=J
      DO 17 I=2,J
 17   OCFS(I,K)=DATA(I)
 18   M=IEND(ID)
      RO = 0.
C     ADD HYDROGRAPHS
C     CONVERT KK TO ID
      IF(KK.GT.0)THEN
      ID=DATA(1)
      DT(ID)=DT(L)
      ENDIF
      DO 20 I=1,M3
      OCFS(I,ID)=OCFS(I,ID1)+OCFS(I,ID2)
      IF (OCFS(I,ID) - PEAK(ID)) 20,20,19
 19   PEAK(ID) = OCFS(I,ID)
 20   RO = RO + OCFS(I,ID)
      DA(ID)=DA(ID1)+DA(ID2)
      IF (PEAK(ID) - PEAK(K1)) 21,22,22
 21   PEAK(ID) = PEAK(K1)
 22   IF (M-M3) 25,25,23
 23   M3 = M3 + 1
      DO 24 I = M3,M
      OCFS(I,ID) = OCFS (I,K1)
 24   RO = RO + OCFS(I,ID)
 25   ROIN(ID) =RO * DT(ID)*3600
 27   RETURN
C
 28   FORMAT(   'ADD HYD',T21,'ID=',I1,T29,' HYD NO=',I3,T45,'ID I=',I1,
     &T60,'ID II=',I1)
 101  FORMAT(T10,'ONE HYDROGRAPH BEING ADDED IS ZERO')
      END
C
C
C ----------------------------------------
C
      SUBROUTINE SRC
```

```
C
C ----------------------------------------
C
C     THIS SUBROUTINE STORES AN ELEVATION - END AREA - FLOW TABLE.
C
      COMMON/BLOCK2/OCFS(300,6),DATA(310),RAIN(300),ROIN(6),
     &IEND(6),DA(6),DT(6),PEAK(6),TIME,KCODE,ICODE
C
      COMMON/BLOCK3/A(20,70),Q(20,70),DEEP(20,70),DP(20),
     &SCFS(20),C(20,6),DIST(6),SEGN(6),ISG(6),PERQ(20,70),
     &TQ(20,6),CC(20),LL(6),INRC,LRC
C
      ID=DATA(1)
      VS=DATA(2)
C     VALLEY SECTION NUMBER
C     REMAINING DATA ARE ELEVATION, AREA, AND FLOW FOR EACH POINT OF
C     THE RATING CURVE
      IF(KCODE.EQ.0)GO TO 2
      J=3
      DO 3 I=1,20
      DATA(J)=DATA(J)/0.3048
      DATA(J+1)=DATA(J+1)/0.093
      DATA(J+2)=DATA(J+2)/0.02832
      J=J+3
3     CONTINUE
2     EMIN=DATA(3)
      J=3
      DO 1 I=1,20
      DEEP(I,ID)=DATA(J)-EMIN
      A(I,ID)=DATA(J+1)
      Q(I,ID)=DATA(J+2)
      J=J+3
1     CONTINUE
      RETURN
      END
C
C
C ----------------------------------------
C
      SUBROUTINE CMPRC
C
C ----------------------------------------
C
C     THIS SUBROUTINE COMPUTES THE DISCHARGE END-AREA ELEVATION
C     RELATIONSHIP FOR A VALLEY SECTION.
C
C     IF MUTIPLE ROUTING INVOKED -
C     COMPUTES SEPARATE RATING CURVES FOR EACH SEGMENT
C     ALSO % FLOW AT EACH ELEVATION FOR SEPARATE SEGMENTS
C
C     IF MOMENTUM EXCHANGE INVOKED
C     COMPUTES THE RATING CURVE USING REDEFINED AREA AND WETTED
C     PERIMETER CALCULATION - KNIGHT TECHNIQUE
C     FOUR OPTIONS
C
C     NOTE --- MOMENTUM EXCHANGE REDEFINITIONS USED "ONLY "
C     FOR OUT-OF-BANK ELEVATIONS
C
```

```
C     MULTIPLE ROUTING AND MOMENTUM EXCHANGE OPERATES INDEPENDANTLY
C
      COMMON/BLOCK2/QCFS(300,6),DATA(310),RAIN(300),ROIN(6),
     &IEND(6),DA(6),DT(6),PEAK(6),TIME,KCODE,ICODE
C
      COMMON/BLOCK3/A(20,70),Q(20,70),DEEP(20,70),DP(20),
     &SCFS(20),C(20,6),DIST(6),SEGN(6),ISG(6),PERQ(20,70),
     &TQ(20,6),CC(20),LL(6),INRC,LRC
      DIMENSION MMM(6),W(6),XM(70)
      INTEGER COUNT
C
C     NEW VARIABLES USED
C     MMM=1 LEFT FLOODPLAIN ADJACENT TO CHANNEL
C     MMM=2 CHANNEL
C     MMM=3 RIGHT FLOODPLAIN ADJACENT TO CHANNEL
C     W WIDTH OF CHANNEL SEGMENT
C     H CHANNEL BANKFULL DEPTH (WHERE ADJACENT SEGMENT IS INUNDATED)
C     XM MINIMUM ELEVATION IN SEGMENT
C
      ID=DATA(1)
C     STORAGE LOCATION NUMBER. (1-6)
      IT=DATA(2)
C     MOMENTUM EXCHANGE INCLUSION
      MR=DATA(3)
C     MULTIPLE ROUTING INCLUSION
      VS=DATA(4)
C     VALLEY SECTION IDENTIFICATION NUMBER.
      NSEG=DATA(5)
C     NUMBER OF SEGMENTS IN THE VALLEY SECTION.
      IF(KCODE.EQ.0)GOTO 1
      DATA(6)=DATA(6)/0.3048
      DATA(7)=DATA(7)/0.3048
    1 ELO=DATA(6)
      EMAX=DATA(7)
C     MAXIMUM ELEVATION FOR COMPUTATIONS.
      SLOPE1=DATA(8)
C     CHANNEL SLOPE.
      SLOPE2=DATA(9)
C     FLOODPLAIN SLOPE.
      DIF=(EMAX-ELO)/19.
      C(1,ID)=ELO
      DO 2 I=2,20
    2 C(I,ID)=C((I-1),ID)+DIF
C     SET AREA AND DISCHARGE ARRAYS = 0.
      DO 3 K=1,NSEG
      W(K)=0
    3 MMM(K)=0
      IF(MR.GT.0.0)THEN
      DO 4 I=1,20
      A(I,ID)=0
    4 Q(I,ID)=0
      ELSE
      DO 5 J=10*ID+1,10*ID+NSEG
      DO 5 I=1,20
      A(I,ID)=0
      Q(I,J)=0
      TQ(I,ID)=0
    5 PERQ(I,J)=0
```

```
      ENDIF
      J=10
      COUNT=0
C     READ N VALUES AND SEGMENT BORDER POINTS.
      DO 6 I=1,NSEG
      SEGN(I)=DATA(J)
      IF(SEGN(I).LT.0)COUNT=1
      IF(KCODE.NE.0)DATA(J+1)=DATA(J+1)/0.3048
      DIST(I)=DATA(J+1)
6     J=J+2
      IF(COUNT.EQ.0)WRITE(6,7)
C     REMAINING DATA ITEMS ARE DISTANCES AND ELEVATIONS.
      IF(KCODE.EQ.0)GOTO 8
      DO 9 I=J,310
9     DATA(I)=DATA(I)/0.3048
8     JJJ=J
      DO 10 I=1,NSEG
11    J=J+2
      IF (DATA(J)-DIST(I))11,12,12
12    ISG(I) = J + 1
10    CONTINUE
C     COMPUTE CHANNEL WIDTH
      IF(IT.LT.1.AND.COUNT.EQ.1)WRITE(6,13)
      IT=2
      IF(COUNT.EQ.1.AND.IT.GT.0)WRITE(6,14)IT
      J=10
      DO 15 K=1,NSEG
      SELEV=0
      IF(SEGN(K))16,17,17
17    IF(K.EQ.1)GOTO 21
      IF(SEGN(K-1))19,18,18
18    GOTO 15
21    IF(SEGN(K+1))20,15,15
C     LEFT HAND FLOODPLAIN
20    MMM(K)=1
      GOTO 15
C     CHANNEL
16    IF(K.EQ.1.OR.K.EQ.NSEG)THEN
      WRITE(6,70)
      IT=2
      GOTO 68
      ENDIF
      W(K)=(DATA(ISG(K)-1)-DATA(ISG(K-1)-1))/2
      MMM(K)=2
      GOTO 15
C     RIGHT HAND FLOODPLAIN
19    MMM(K)=3
15    CONTINUE
C     COMPUTE DISCHARGES AND END AREAS FOR EACH SEGMENT.
68    DO 22 K=1,NSEG
      J=JJJ
      JJJ1=JJJ+1
      IF (SEGN(K)) 23,23,24
23    SLOPE=SLOPE1
      GO TO 25
24    SLOPE=SLOPE2
25    SLPN=1.486*SLOPE**.5
C     COMPUTE AREA AND DISCHARGE FOR SEGMENT.
```

```
      DO 26 I=2,20
      AA=0.
      P=0.
      J=JJJ-1
      DEP2=0.
27    J=J+2
      IF (J-ISG(K)) 28,28,29
29    IF(AA-.001)26,26,37
28    IF(DATA(J)-C(I,ID)) 32,27,27
32    DEP1=C(I,ID)-DATA(J)
      IF (J-JJJ1) 33,33,34
34    XL=DATA(J-1)-DATA(J-3)
      DEP3=ABS(DATA(J-2)-DATA(J))
      XL=XL*DEP1/DEP3
35    AA=AA+XL*(DEP1+DEP2)/2.
      P=P+SQRT((DEP1-DEP2)**2+XL**2)
33    DEP2=DEP1
      J=J+2
      IF (J-ISG(K)) 36,36,37
36    IF (DATA(J)-C(I,ID)) 38,38,39
38    DEP1=C(I,ID)-DATA(J)
      XL=DATA(J-1)-DATA(J-3)
      GOTO 35
39    DEP1=0
      XL=DATA(J-1)-DATA(J-3)
      DEP3=ABS(DATA(J-2)-DATA(J))
      XL=XL*DEP2/DEP3
      AA=AA+XL*(DEP1+DEP2)/2.
      P=P+SQRT((DEP1-DEP2)**2+XL**2)
      DEP2=0.
      GOTO 27
C     CHECK IF MOMENTUM EXCHANGE INVOKED
C     CHECK IF OUT-OF-BANK
37    IF(MMM(K).LT.1)GOTO 40
      IF(MMM(K).EQ.1)GOTO 41
      IF(MMM(K).EQ.3)GOTO 42
C     CHANNEL
C     CHECK OUT-OF-BANK
      IF(C(I,ID).LE.DATA(ISG(K)).AND.C(I,
     &ID).LE.DATA(ISG(K-1)))GOTO40
      H=(DATA(ISG(K))+DATA(ISG(K-1)))/2-ELO
      IF(IT.LE.2)GOTO 43
C     AREA METHOD 3 AND 4
      AA=AA/2+(W(K)*H)
43    IF(IT.EQ.1.OR.IT.EQ.3)THEN
C     WETTED PERIMETER METHOD 1 AND 3
      P=P-(2*(C(I,ID)-C((I-1),ID)))+2*H
      ENDIF
      IF(IT.EQ.4)THEN
C     WETTED PERIMETER METHOD4
      P=P+(2*((C(I,ID)-C((I-1),ID))**2+W(K)**2)**0.5)
      ENDIF
      GOTO 40
C     LEFT HAND FLOODPLAIN
41    L=K+1
      GOTO 44
C     RIGHT HAND FLOODPLAIN
42    L=K-1
```

```
44    IF(IT.LT.3)GOTO 45
      AA=AA+((C(I,ID)-C((I-1),ID))*W(L)/2)
45    IF(IT.EQ.2)THEN
      P=P+(C(I,ID)-C((I-1),ID))
      ENDIF
40    R=AA/P
C      REMOVED ALOGGRITHM BELOW
C      SGN=SEGN(K) - .0025*R
      IF(SEGN(K).LT.0.0)THEN
      SGN=-SEGN(K)
      GOTO 46
      ENDIF
      SGN=SEGN(K)
46    IF(MR.LT.1) GOTO 47
C     COMPUTE SEPARATE R.CURVES FOR EACH SEGMENT
      II=10*ID+K
      Q(I,II)=Q(I,II)+AA*R**.6667*SLPN/SGN
      A(I,II)=A(I,II)+AA
      GOTO 26
C     ADD DISCHARGES AND AREAS FOR ALL SEGMENTS TO OBTAIN TOTALS FOR
C     VALLEY SECTION.
47    Q(I,ID)=Q(I,ID)+AA*R**.66667*SLPN/SGN
      A(I,ID)=A(I,ID)+AA
26    CONTINUE
      JJJ=J-3
22    CONTINUE
      IF(ICODE.EQ.0)GO TO 48
      IF(MR.LT.1)GOTO 49
C     FIND MIN ELEV IN EACH SEGMENT
      J=13+2*NSEG
      DO 50 M=1,NSEG
      IF(M.EQ.1)THEN
      XM(10*ID+M)=DATA(ISG(M))
      GOTO 51
      ENDIF
      XM(10*ID+M)=DATA(ISG(M-1))
51    IF(J.GT.ISG(M))GOTO 50
      IF(DATA(J).LT.XM(10*ID+M))THEN
      XM(10*ID+M)=DATA(J)
      ENDIF
      J=J+2
      GOTO 51
50    CONTINUE
      DO 52 J=10*ID+1,10*ID+NSEG
      WRITE(6,30)J
      DO 52 I=1,20
      C1=C(I,ID)*0.3048
      A1=A(I,J)*0.093
      Q1=Q(I,J)*0.02832
      DEEP(I,J)=C(I,ID)-XM(J)
      IF(DEEP(I,J).LT.0)THEN
      DEEP(I,J)=0
      ENDIF
      WRITE(6,55) C1,A1,Q1
52    CONTINUE
      GOTO 53
49    WRITE(6,31)VS
      DO 54 I=1,20
```

```
      C1=C(I,ID)*0.3048
      A1=A(I,ID)*0.093
      Q1=Q(I,ID)*0.02832
      DEEP(I,ID)=C(I,ID)-ELO
      WRITE(6,55)C1,A1,Q1
54    CONTINUE
      RETURN
48    IF(MR.LT.1)GOTO 56
C     FIND MIN ELEV IN SEGMENT
      J=13+2*NSEG
      DO 57 M=1,NSEG
      IF(M.EQ.1)THEN
      XM(10*ID+M)=DATA(ISG(M))
      GOTO 58
      ENDIF
      XM(10*ID+M)=DATA(ISG(M-1))
58    IF(J.GT.ISG(M))GOTO 57
      IF(DATA(J).LT.XM(10*ID+M))THEN
      XM(10*ID+M)=DATA(J)
      ENDIF
      J=J+2
      GOTO 58
57    CONTINUE
      DO 59 J=10*ID+1,10*ID+NSEG
      WRITE(6,60) J
      DO 59 I=1,20
      DEEP(I,J)=C(I,ID)-XM(J)
      IF(DEEP(I,J).LT.0)THEN
      DEEP(I,J)=0
      ENDIF
      WRITE(6,61) C(I,ID),A(I,J),Q(I,J)
59    CONTINUE
      GOTO 53
56    WRITE(6,62)VS
      DO 63 I=1,20
      DEEP(I,ID)=C(I,ID)-ELO
      WRITE (6,55) C(I,ID),A(I,ID),Q(I,ID)
63    CONTINUE
      RETURN
C     COMPUTE % FLOW IN EACH SEGMENT
53    DO 64 I=10*ID+1,10*ID+NSEG
      DO 64 J=1,20
      TQ(J,ID)=TQ(J,ID)+Q(J,I)
64    CONTINUE
      DO 65 I=1,NSEG
      II=10*ID+I
      WRITE(6,66)II
      DO 65 J=1,20
      PERQ(J,II)=Q(J,II)/TQ(J,ID)
      IF(J.EQ.1) THEN
      PERQ(J,II)=0
      ENDIF
      IF(PERQ(2,II).EQ.1.0)THEN
      PERQ(1,II)=1.0
      ENDIF
      IF(ICODE.GT.0)THEN
      C(J,ID)=C(J,ID)*0.3048
      ENDIF
```

```
      WRITE(6,67) C(J,ID),PERQ(J,II)
      IF(ICODE.GT.0)THEN
      C(J,ID)=C(J,ID)/0.3048
      ENDIF
65    CONTINUE
      RETURN

62    FORMAT(T42,'RATING CURVE VALLEY SECTION ',F5.1/T46,'WATER',T56,
     &'FLOW',T66,'FLOW'/T45,'SURFACE',T56,'AREA',T66,'RATE'/T46,'ELEV',
     &T56,'SQ FT',T66,'CFS')
60    FORMAT(T42,'RATING CURVE FOR SEGMENT ',I5.1/T46,'WATER',T56,
     &'FLOW',T66,'FLOW'/T45,'SURFACE',T56,'AREA',T66,'RATE'/T46,'ELEV',
     &T56,'SQ FT',T66,'CFS')
31    FORMAT(T42,'RATING CURVE VALLEY SECTION',F5.1/T46,
     &'WATER',T56,'FLOW',T66,'FLOW'/T45,'SURFACE',T56,'AREA',
     &T66,'RATE'/T46,'ELEV',T56,'SQ M',T66,'CMS')
30    FORMAT(T42,'RATING CURVE FOR SEGMENT  ',I5.1/T46,
     &'WATER',T56,'FLOW',T66,'FLOW'/T45,'SURFACE',T56,'AREA',
     &T66,'RATE'/T46,'ELEV',T56,'SQ M',T66,'CMS')
61    FORMAT (40X,F10.2,2F10.1)
55    FORMAT (40X,3F10.2)
66    FORMAT (T42,'% DISCHARGE IN SEGMENT  ',I2.1/T46,
     &'ELEV',T55,'PERCENT')
67    FORMAT(40X,F10.2,2F10.3)
70    FORMAT(T10,'ERROR - NEED FLD PLAIN SEG BOTH SIDES OF CHANNEL',
     &'- USING METHOD 2')
14    FORMAT(T42,'MOMENTUM EXCHANGE METHOD',1X,I5.1)
13    FORMAT(T10,'NO MOMENTUM EXCHANGE ROUTINE SELECTED',/T10,
     &'- USING METHOD 2')
7     FORMAT(T10,'NO CHANNEL SEGMENTS SPECIFIED ',/T10,
     & '- USING METHOD 2')
      END
C
C
C ==========================================
C
      SUBROUTINE STT
C
C ==========================================

C     THIS SUBROUTINE STORES A DEPTH - FLOW - TRAVEL TIME TABLE.

      COMMON/BLOCK2/OCFS(300,6),DATA(310),RAIN(300),ROIN(6),
     &IEND(6),DA(6),DT(6),PEAK(6),TIME,KCODE,ICODE

      COMMON/BLOCK3/A(20,70),Q(20,70),DEEP(20,70),DP(20),
     &SCFS(20),C(20,6),DIST(6),SEGN(6),ISG(6),PERQ(20,70),
     &TQ(20,6),CC(20),LL(6),INRC,LRC

      ID=DATA(1)
      REACH=DATA(2)
      MET1=DATA(5)
      IF(MET1.EQ.0)GO TO 2
      DATA(3)=DATA(3)/0.3048
      J=6
      DO 3 I=1,19
      DATA(J)=DATA(J)/0.3048
      DATA(J+1)=DATA(J+1)/0.02832
```

```
3     J=J+3
2     XL=DATA(3)
      SLOPE=DATA(4)
      DIST(ID)=SLOPE*XL
      J=6
      DO 1 I=1,19
      DP(I)=DATA(J)
      SCFS(I)=DATA(J+1)
      CC(I)=DATA(J+2)
1     J=J+3
      RETURN
      END
C
C
C ========================================
C
      SUBROUTINE CMPTT
C
C ========================================

C     THIS SUBROUTINE COMPUTES THE TRAVEL TIME AT GIVEN
C     DISCHARGE RATES
C
C     IF MULTIPLE ROUTING INVOKED, COMPUTES TRAVEL TIME TABLE FOR
C     THE ONE SEGMENT SPECIFIED - OTHERWISE ALL SEGMENTS TOGETHER
C
C     NOTE -- FOR MULTIPLE ROUTINE NEED TO REPEAT THIS ROUTINE AND ROUTE
C     FOR "EACH" SEGMENT

      COMMON/BLOCK2/OCFS(300,6),DATA(310),RAIN(300),ROIN(6),
     &IEND(6),DA(6),DT(6),PEAK(6),TIME,KCODE,ICODE

      COMMON/BLOCK3/A(20,70),Q(20,70),DEEP(20,70),DP(20),
     &SCFS(20),C(20,6),DIST(6),SEGN(6),ISG(6),PERQ(20,70),
     &TQ(20,6),CC(20),LL(6),INRC,LRC

      DIMENSION CFS(300)

      ID=DATA(1)
      REACH=DATA(2)
      NOVS=DATA(3)
      IF(KCODE.NE.0)DATA(4)=DATA(4)/0.3048
      XL=DATA(4)
      SLOPE=DATA(5)
      DIST(ID)=SLOPE*XL
      XLD36 = XL / 3600.
      MR=DATA(6)
C     MULTIPLE ROUTING
      INRC=DATA(7)
C     RATING CURVE AT TOP OF REACH
      LRC=DATA(8)
C     RATING CURVE AT DOWNSTREAM END
C     ZERO ARRAYS
      IF(NOVS.GT.2.AND.MR.GT.0)THEN
      WRITE(6,40)
      RETURN
      ENDIF
      DO 1 J=1,20
```

```
      DATA (J)=0.
1     CFS(J)=0.
C     MULTIPLE ROUTING COMPUTATION
      IF(MR.LT.1)GOTO 30
      WRITE(6,37)
      ID1=INRC
      GOTO 2
30    ID1=1
C     FIND RATING CURVE WITH SMALLEST MAXIMUM FLOW RATE
2     QMIN=Q(20,ID1)
      MIN=ID1
      GO TO 4
31    ID1=LRC
      GOTO 32
3     ID1=ID1+1
32    IF (QMIN-Q(20,ID1)) 4,4,2
4     IF(MR.LT.1)GOTO33
      IF(ID1.EQ.INRC)GOTO 31
      IF(ID1.EQ.LRC)GOTO5
      WRITE(6,*)'ERROR only two r.curves allowed for m.routing'
      RETURN
33    IF (ID1-NOVS) 3,5,5
5     I=1
      LL(ID)=0
C     SET SCFS ARRAY EQUAL TO Q ARRAY OF LOWEST RATING CURVE
      DO 6 J=2,20
      SCFS(I)=Q(J,MIN)
      IF(MR.LT.1)GOTO 6
      IF(PERQ(J,MIN).LT.0.001)THEN
      LL(ID)=LL(ID)+1
      ENDIF
6     I=I+1
C     COMPUT END AREA AND DEPTH
      DO 9 ID1=1,NOVS
      IF(MR.LT.1) GOTO 34
      IF(ID1.EQ.1)THEN
      ID1=INRC
      GOTO 34
      ENDIF
      ID1=LRC
34    M=1+LL(ID)
      N=2+LL(ID)
      DO 36 J=M,19
      DO 7 I=N,20
      IF (Q(I,ID1)-SCFS(J)) 7,17,8
7     CONTINUE
17    DATA (J)=A(I,ID1)+DATA(J)
      CFS(J)=DEEP(I,ID1)+CFS(J)
      GO TO 36
8     XY=(SCFS(J)-Q(I-1,ID1))/(Q(I,ID1)-Q(I-1,ID1))
      DATA (J)=A(I-1,ID1)+XY*(A(I,ID1)-A(I-1,ID1))+DATA(J)
      CFS(J)=DEEP(I-1,ID1)+XY*(DEEP(I,ID1)-DEEP(I-1,ID1))+CFS(J)
36    CONTINUE
      IF(MR.LT.1) GOTO 9
      IF(ID1.EQ.LRC)GOTO 35
      ID1=1
9     CONTINUE
35    XNOVS=NOVS
```

```
      IF(ICODE.EQ.0)GO TO 19
      WRITE(6,20)REACH
      GO TO 21
19    WRITE(6,13)REACH
      ID1=MIN
21    DO 10 I=M,19
      AVAREA = DATA (I) / XNOVS
      DP (I) = CFS(I) / XNOVS
      S = AVAREA * XLD36
      CC(I)=S/SCFS(I)
      IF(SCFS(I).EQ.0) THEN
      CC(I)=0
      ENDIF
      IF(ICODE.EQ.0)GO TO 24
      DP1=DP(I)*0.3048
      SCFS1=SCFS(I)*0.02832
      WRITE(6,14)DP1,SCFS1,CC(I)
      GO TO 10
24    WRITE(6,14)DP(I),SCFS(I),CC(I)
10    CONTINUE
      RETURN
C
13    FORMAT(1H0,T46,'TRAVEL TIME TABLE'/T54,'REACH',F5.1//T46,'WATER',T
     &56,'FLOW',T65,'TRAVEL'/T46,'DEPTH',T56,'RATE',T66,'TIME'/T46,'FEET
     &',T56,'CFS',T66,'HRS')
14    FORMAT (40X,F10.2,F10.0,F10.2)
20    FORMAT(1H0,T46,'TRAVEL TIME TABLE'/T54,'REACH',F5.1//T46,'WATER',T
     &56,'FLOW',T65,'TRAVEL'/T46,'DEPTH',T56,'RATE',T66,'TIME'/T46,
     &"METER",T56,'CMS',T66,'HRS')
37    FORMAT(1H0,T24,'MULTIPLE ROUTING INVOKED')
40    FORMAT(T10,'ONLY TWO RATING CURVES REQUIRED FOR MULTIPLE ROUTING')
      END
C
C
C ---------------------------------------
C
      SUBROUTINE ROUTE
C
C ---------------------------------------

C     THIS SUBROUTINE ROUTES A HYDROGRAPH THROUGH A REACH WITH THE
C     NEW VSC METHOD OF FLOOD ROUTING. THIS METHOD ACCOUNTS FOR THE
C     VARIATION IN WATER SURFACE SLOPE.
C
C     IF MULTIPLE ROUTING INVOKED - COMPUTES PROPORTION INFLOW
C     FOR ONE SEGMENT
C
C     BUT  -----  ONLY ROUTES ONES SEGMENT AT A TIME
C     REPEAT TRAVEL TIME TABLE AND ROUTE COMMANDS FOR EACH SEGMENT
C     AND ADD OUTFLOWS

      COMMON/BLOCK2/OCFS(300,6),DATA(310),RAIN(300),ROIN(6),
     &IEND(6),DA(6),DT(6),PEAK(6),TIME,KCODE,ICODE

      COMMON/BLOCK3/A(20,70),Q(20,70),DEEP(20,70),DP(20),
     &SCFS(20),C(20,6),DIST(6),SEGN(6),ISG(6),PIRQ(20,70),
     &TQ(20,6),CC(20),LL(6),INRC,LRC

```

```
      DIMENSION DOCFS(300,6),CFS(300)

C     New variables used
C     DOCFS copy inflow array (preserve original OCFS)
C     P percentage of OCFS (multiple routing)
C     DTDT copy inflow time increment (preserves DT(IDH))
C     TM increments DT
      ID=DATA(1)
      NHD=DATA(2)
      IDH=DATA(3)
      DT(ID)=DATA(4)
      DTDT=DT(IDH)
      DA(ID)=DA(IDH)
      M=IEND(IDH)
      MR=DATA(5)
C     CHECK: IF M.ROUTING ID.NE.IDH
      IF(MR.GT.0.AND.ID.EQ.IDH)THEN
      WRITE(6,*)'ERROR - FOR M.ROUTING ID MUST NOT BE SAME AS IDH'
      RETURN
      ENDIF
C     MULTIPLE ROUTING INCLUDED
C     SET UP DUMMY ARRAY
      DO 51 I=1,IEND(IDH)
   51 DOCFS(I,IDH)=OCFS(I,IDH)
C     MULTIPLE ROUTING
C     COMPUTE DISTRIBUTED FLOW IN SEGMENT
      IF(MR.LT.1)GOTO 50
      II=INRC/10
      NN=INRC-10*II
      IF(ICODE.GT.0)GOTO 53
      WRITE(6,60)NN
      GOTO 55
   53 WRITE(6,61)NN
   55 TM=TIME-DTDT
      JJJJ=0
      DO 52 J=1,IEND(IDH)
      TM=TM+DTDT
      DO 56 K=2,20
      IF(DOCFS(J,IDH)-TQ(K,II))57,58,56
   56 CONTINUE
      WRITE(6,*)'FAILED - RATING CURVE EXCEEDED'
      RETURN
   58 DOCFS(J,IDH)=PERQ(J,INRC)*DOCFS(J,IDH)
      GOTO 54
   57 ST=C(K,II)-(((TQ(K,II)-DOCFS(J,IDH))*(C(K,II)-C((K-1),II)))/(TQ
     &(K,II)-TQ(K-1,II)))
      P=PERQ(K,INRC)-(((C(K,II)-ST)*(PERQ(K,INRC)-PERQ((K-1),
     &INRC)))/(C(K,II)-C((K-1),II)))
      DOCFS(J,IDH)=P*DOCFS(J,IDH)
   54 IF(DOCFS(J,IDH).EQ.0)THEN
      JJJJ=JJJJ+1
      IF(JJJJ.EQ.IEND(IDH))THEN
      WRITE(6,*)' NO FLOW IN SEGMENT'
      RETURN
      ENDIF
      GOTO 52
      ENDIF
      IF(ICODE.GT.0)THEN
```

```
      DOCFS(J,IDH)=DOCFS(J,IDH)*0.0283168
      ENDIF
      WRITE(6,59) TM,P,DOCFS(J,IDH)
      IF(ICODE.GT.0)THEN
      DOCFS(J,IDH)=DOCFS(J,IDH)/0.0283168
      ENDIF
52    CONTINUE
C     IF ID AND IDH ARE EQUAL, ADD 1 TO IDH
50    IF(MR.LT.1)THEN
      LL(ID)=0
      ENDIF
      IF (ID-IDH) 3,1,3
1     IDORG=IDH
      IDH=IDH+1
      DO 2 I=1,M
2     DOCFS(I,IDH)=DOCFS(I,IDH-1)
      DT(IDH)=DT(IDH-1)
      PEAK(IDH)=PEAK(IDH-1)
3     NERRT=0
      PEAK(ID) = 1.
      RO = 0.
      N=19
      OCFS(1,ID)=0.
      S = 0.
      T1 = CC(1)
      J=1
      GUES = 1.
      CFS(1)=0.
C     IF ROUTING INTERVAL IS NOT EQUAL TO TIME INCREMENT OF INFLOW
C     HYDROGRAPH, INTERPOLATE
      IF (DT(ID)-DT(IDH)) 8,15,4
4     TID=DT(ID)
      TIDH=0.
      DO 7 I=2,M
      TIDH=TIDH+DT(IDH)
      IF (TID-TIDH) 6,5,7
5     J=J+1
      CFS(J)=DOCFS(I,IDH)
      TID=TID+DT(ID)
      GO TO 7
6     J=J+1
      CFS(J)=DOCFS(I-1,IDH)+((TID-TIDH+DT(IDH))/DT(IDH))*(DOC
     &FS(I,IDH)-DOCFS(I-1,IDH))
      TID=TID+DT(ID)
7     CONTINUE
      GO TO 13
8     TIDH=0.
      TID=DT(ID)
      DO 12 I=2,M
      TIDH=TIDH+DT(IDH)
9     IF (TIDH-TID) 12,10,11
10    J=J+1
      CFS(J)=DOCFS(I,IDH)
      TID=TID+DT(ID)
      IF (J-300) 12,13,13
11    J=J+1
      CFS(J)=DOCFS(I-1,IDH)+((TID-TIDH+DT(IDH))/DT(IDH))*(DOC
     &FS(I,IDH)-DOCFS(I-1,IDH))
```

```
      TID=TID+DT(ID)
      IF (J-300) 9,13,13
12    CONTINUE
13    DT(IDH)=DT(ID)
      M=J
      DO 14 I=2,M
14    DOCFS(I,IDH)=CFS(I)
C     IF INFLOW IS ZERO, SO IS OUTFLOW
15    DO 16 L=2,M
      IF (DOCFS(L,IDH)) 16,16,49
16    OCFS(L,ID)=0.
C     ROUTE
49    DATA (L-1) = 0.
      DO 42 I=L,300
      IF (I-M) 18,18,17
17    DOCFS(I,IDH)=DOCFS(I-1,IDH)*.9
18    AVIN=(DOCFS(I,IDH)+DOCFS(I-1,IDH))/2.
      SIA = AVIN + S
      J=1
C     DETERMINE DEPTH AND TRAVEL TIME OF INFLOW
      IF (DOCFS(I,IDH)-SCFS(1+LL(ID))) 19,23,20
19    DI2 = (DOCFS(I,IDH) / SCFS(1+LL(ID))) * DP(1+LL(ID))
      TI2 = CC(1+LL(ID))
      GO TO 25
20    JJJ=2
      IF(LL(ID).GT.0)THEN
      JJJ=LL(ID)+2
      ENDIF
      DO 21 J=JJJ,N
      IF (DOCFS(I,IDH)-SCFS(J)) 24,23,21
21    CONTINUE
      IF (NERRT) 22,22,36
22    WRITE (6,46)
      NERRT=1
      GO TO 36
23    DI2=DP(J)
      TI2 = CC(J)
      GO TO 25
24    RATIO=(DOCFS(I,IDH)-SCFS(J-1))/(SCFS(J)-SCFS(J-1))
      DI2=DP(J-1)+RATIO*(DP(J)-DP(J-1))
      TI2=CC(J-1)+RATIO*(CC(J)-CC(J-1))
25    DO 35 IT=1,10
      J=1
C     DETERMINE DEPTH AND TRAVEL TIME OF OUTFLOW
      IF (GUES-SCFS(1+LL(ID))) 26,29,27
26    DO2 = (GUES / SCFS(1+LL(ID)))* DP(1+LL(ID))
      TO2 = CC(1+LL(ID))
      GO TO 31
27    DO 28 J=JJJ,N
      IF (GUES-SCFS(J)) 30,29,28
28    CONTINUE
      J=N
29    DO2=DP(J)
      TO2=CC(J)
      GO TO 31
30    RATIO=(GUES-SCFS(J-1))/(SCFS(J)-SCFS(J-1))
      DO2=DP(J-1)+RATIO*(DP(J)-DP(J-1))
      TO2=CC(J-1)+RATIO*(CC(J)-CC(J-1))
```

```
C      FIND WATER SURFACE SLOPE
31     DDD=DIST(ID)/(DIST(ID)+DI2-DO2)
       IF (DDD-.01) 32,32,33
32     GUES=DOCFS(I-1,IDH)
       GO TO 35
33     T2 = .5 * (TI2 + TO2)
       T2=T2*SQRT(DDD)
       T = T1 + T2
C      COMPUTE ROUTING COEFFICIENT
       COEF =(2. * DT(ID)) / (T+DT(ID))
       O2 = COEF * SIA
       TRY1 = GUES
       RATIO=O2/(GUES+.1E-20)
       DIFF=ABS(1.-RATIO)
C      TEST FOR CONVERGENCE
       IF (DIFF-0.001) 37,37,34
34     GUES=O2
35     CONTINUE
       OCFS(I,ID)=DATA(I-1)*SIA
       DATA(I) = DATA(I-1)
       WRITE (6,47) I,OCFS(I,ID)
       GO TO 38
36     OCFS(I,ID)=DATA(I-1)*SIA
       DATA(I) = DATA(I-1)
       GO TO 38
37     OCFS(I,ID)=O2
       DATA (I) = COEF
C      COMPUTE NEW STORAGE
38     S = SIA - OCFS(I,ID)
       T1 = T2
       RO = RO + OCFS (I,ID)
       IF (OCFS(I,ID) - OCFS(I-1,ID)) 39,40,40
39     IF(OCFS(I,ID) -1.) 43,43,42
40     IF(OCFS(I,ID) - PEAK(ID)) 42,42,41
41     PEAK(ID)=OCFS (I,ID)
42     CONTINUE
       I=300
43     IEND(ID)=I
       ROIN(ID) = RO*DT(ID)*3600
C      COMPUTE % VOLUME OUTFLOW/VOLULE INFLOW
       IF(IDORG.NE.0)IDH=IDORG
       DIFF1=ABS(ROIN(ID)/ROIN(IDH))*100
       WRITE(6,62)ID,DIFF1,IDH
       DT(IDH)=DTDT
       RETURN
C
46     FORMAT(1H0, 'TRAVEL TIME TABLE EXCEEDED')
47     FORMAT(T10,'PROBLEM FAILED TO CONVERGE AFTER 10 ITERATIONS. CONVERG
      &ENCE WAS FORCED.'/T20,'OUTFLOW NUMBER = ',I4,'RATE =',F10.2)
60     FORMAT(1H0,T40,'INFLOW FOR SEGMENT',I5.1/T30,'HOURS',T40,
      &'PERCENT',T52,'CFS')
61     FORMAT(1H0,T40,'INFLOW FOR SEGMENT',I5.1/T30,'HOURS',
      &T40,'PERCENT',T52,'CUMECS')
59     FORMAT(25X,F10.3,2F10.3,3F10.3)
62     FORMAT(T6,'CHECK- VOLUME OF OUTFLOW HYDROGRAPH',I2,' IS',F10.3,
      $'% OF INFLOW HYDROGRAPH',2I2)
       END
C
```

```
C
C ===========================================
C
      SUBROUTINE RESVO
C
C ===========================================

C     THIS SUBROUTINE ROUTES A HYDROGRAPH THROUGH A RESERVOIR WITH THE
C     STORAGE-INDICATION METHOD.

      COMMON/BLOCK2/OCFS(300,6),DATA(310),RAIN(300),ROIN(6),
     &IEND(6),DA(6),DT(6),PEAK(6),TIME,KCODE,ICODE

      COMMON/BLOCK3/A(20,70),Q(20,70),DEEP(20,70),DP(20),
     &SCFS(20),C(20,6),DIST(6),SEGN(6),ISG(6),PERQ(20,70),
     &TQ(20,6),CC(20),LL(6),INRC,LRC

      ID=DATA(1)
      NHD=DATA(2)
      IDH=DATA(3)
      NERES=0
      DT(ID)=DT(IDH)
      RO = 0.
      DA(ID)=DA(IDH)
      PEAK(ID) = 1.
      J=1
      I=4
C     REMAINING DATA ARE FLOW AND STORAGE VALUES
      IF(KCODE.EQ.0)GO TO 25
      DATA(I)=DATA(I)/0.02832
      DATA(I+1)=DATA(I+1)/1.21968
25    SCFS(J)=DATA(I)
      STORE1=DATA(I+1)*12.1
      STORE=STORE1
C     COMPUTE STORAGE COEFFICIEN  ARRAY C
1     CC(J)=(SCFS(J)/2.)+(STORE/DT(ID))
      I=I+2
      J=J+1
      IF (J-20) 2,2,3
2     IF(KCODE.EQ.0)GO TO 26
      DATA(I)=DATA(I)/0.02832
      DATA(I+1)=DATA(I+1)/1.21968
26    SCFS(J)=DATA(I)
      STORE=DATA(I+1)*12.1
      IF (SCFS(J)-.001) 3,3,1
3     N=J-1
      OCFS(1,ID)=0.
      S=STORE1/DT(ID)
C     ROUTE
      DO 15 I=2,150
      IF (I-IEND(IDH)) 5,5,4
4     OCFS(I,IDH)=0.0
5     AVIN=(OCFS(I,IDH)+OCFS(I-1,IDH))/2.
      SIA=S+AVIN
C     DETERMINE PROPER C
      DO 6 J=1,N
      IF (SIA-CC(J)) 10,9,6
6     CONTINUE
```

```
      IF (NERES) 7,7,8
7     WRITE (6,19)
      NERES=1
8     RESC=SCFS(N)/CC(N)
C     COMPUT OUTFLOW
      OCFS(I,ID)=RESC*SIA
      GO TO 11
9     OCFS(I,ID)=SCFS(J)
      GO TO 11
10    OCFS(I,ID)=SCFS(J-1)+((SIA-CC(J-1))/(CC(J)-CC(J
     & -1)))*(SCFS(J)-SCFS(J-1))
C     DETERMINE NEW STORAGE
11    S=SIA-OCFS(I,ID)
      RO = RO + OCFS(I,ID)
      IF (OCFS(I,ID)-OCFS(I-1,ID)) 12,13,13
12    IF (OCFS(I,ID)-1.) 16,16,15
13    IF(OCFS(I,ID) - PEAK(ID)) 15,15,14
14    PEAK(ID) = OCFS(I,ID)
15    CONTINUE
      I=150
16    IEND(ID)=I
      ROIN(ID) = RO * DT(ID)*3600
      RETURN
C
19    FORMAT (1H0,33HSTORAGE-DISCHARGE TABLE EXCEEDED.)
      END
C
C
C ==========================================
C
      SUBROUTINE ERROR
C
C ==========================================

C This subroutine determines the error standard deviation and the peak flow
C error for 2 hydrographs (original program retained).
C Assumes that measured is ID1
C In addition, 10 other measures of goodness of fit are calculated.
C All indicies are printed out in metric units.

      COMMON/BLOCK2/OCFS(300,6),DATA(310),RAIN(300),ROIN(6),
     &IEND(6),DA(6),DT(6),PEAK(6),TIME,KCODE,ICODE

      real CFS(300)
      ID1=D..TA(1)
      ID2=DATA(2)
      SSE=0.
           WRITE(6,21)
21         FORMAT(1H0,T33,'TIME',T55,'FLOW 1',T76,
     &     'FLOW 2',T95,'ERROR'/T34,
     &     'HRS',T57,'CMS',T78,'CMS',T97,'CMS')

22    J=1
C If the time increments are not equal, interpolate.

      IF (DT(ID1)-DT(ID2)) 1,8,2
1     L=ID1
      K=ID2
```

```
      GO TO 3
2     L=ID2
      K=ID1
3     M=IEND(L)
      TID=DT(K)
      TIDH=0.
      DO 6 I=2,M
      TIDH=TIDH+DT(L)
      IF (TID-TIDH) 5,4,6
4     J=J+1
      CFS(J)=OCFS(I,L)
      TID=TID+DT(K)
      GO TO 6
5     J=J+1
      CFS(J)=OCFS(I-1,L)+((TID-TIDH+DT(L))/DT(L))*(OCFS(I,L)-OCFS(I-1,L)
     &)
      TID=TID+DT(K)
6     CONTINUE
      IEND(L)=J
      DT(L)=DT(K)
      DO 7 I=2,J
7     OCFS(I,L)=CFS(I)
8     IF (IEND(ID1)-IEND(ID2)) 9,9,10
9     M=IEND(ID1)
      GO TO 11
10    M=IEND(ID2)
11    T2=TIME

      IF (KCODE.EQ.0)THEN
        DO 997 I=1,M
             OCFS(I,ID1)=OCFS(I,ID1)*.02832
997          OCFS(I,ID2)=OCFS(I,ID2)*.02832
      ENDIF

C Determine error - original method

      DO 12 I=1,M
      ERR=OCFS(I,ID1)-OCFS(I,ID2)
              WRITE(6,16)T2,OCFS(I,ID1),OCFS(I,ID2),ERR
16            FORMAT (6X,F12.3,3F12.0)
25            T2=T2+DT(ID1)

C Sum of squares of error

12    SSE=SSE+ERR*ERR
      XM=M

C Error variance

      EVAR=SSE/XM

C Error standard deviation

      ESDEV=SQRT(EVAR)

C Percent error for peak discharge

      ERPK=ABS(PEAK(ID1)-PEAK(ID2))
```

```
      PCTER=(ERPK/PEAK(ID1))*100.

C Other goodness of fit calculations...

      SUM01=0.
      SUM0=0.
      SUM1=0.
      SUM2=0.
      SUM3=0.
      SUM4=0.
      SUM5=0.
      SUM6=0.
      SUM7=0.
      SUM8=0.
      SUM9=0.
      SUM10=0.
      SUM11=0.
      SUM12=0.

      DO 77 I=1,M
        ERR=OCFS(I,ID1)-OCFS(I,ID2)
        IF(OCFS(I,ID1).EQ.0.0.AND.OCFS(I,ID2).NE.0.0)THEN
            LOGERR=ALOG(OCFS(I,ID2))
        ELSE IF(OCFS(I,ID1).NE.0.0.AND.OCFS(I,ID2).EQ.0.0)THEN
            LOGERR=ALOG(OCFS(I,ID1))
        ELSE IF(OCFS(I,ID1).EQ.0.0.AND.OCFS(I,ID2).EQ.0.0)THEN
           LOGERR=0.
        ELSE
           LOGERR=ALOG(OCFS(I,ID1))-ALOG(OCFS(I,ID2))
        ENDIF
        SUM0=OCFS(I,ID1)+SUM0
        SUM01=OCFS(I,ID2)+SUM01
        SUM1=ERR+SUM1
        SUM2=ERR**2+SUM2
        SUM3=LOGERR**2+SUM3
        IF(OCFS(I,ID1).EQ.0.)OCFS(I,ID1)=1.
        SUM4=((ERR/OCFS(I,ID1))**2)+SUM4
77      CONTINUE

      DO 13 I=2,M
        DIFF1=OCFS(I,ID1)-OCFS(I-1,ID1)
        DIFF2=OCFS(I,ID2)-OCFS(I-1,ID2)
        SUM5=((DIFF1-DIFF2)**2)+SUM5
        SUM7=DIFF1+SUM7
        IF(DIFF1.EQ.0.)DIFF1=1.
        SUM6=(((DIFF1-DIFF2)/DIFF1)**2)+SUM6
13      CONTINUE


      SIMMEAN=SUM01/M
      OBSMEAN=SUM0/M
      DIFFM1=SUM7/M

      DO 14 I=2,M
        SUM8=(((OCFS(I,ID1)-OCFS(I-1,ID1))-DIFFM1)**2)+SUM8
        SUM9=((((OCFS(I,ID1)-OCFS(I-1,ID1))/DIFFM1)-1)**2)+SUM9
14      CONTINUE

```

```
      DO 73 I=1,M
        SUM10=((OCFS(I,ID1)-OBSMEAN)**2)+SUM10
        SUM11=(((OCFS(I,ID1)/OBSMEAN)-1)**2)+SUM11
        SUM12=((OCFS(I,ID2)-SIMMEAN)**2)+SUM12
 73     CONTINUE

      SDM=SQRT(SUM10/(M-1))
      SDS=SQRT(SUM12/(M-1))

      DO 115 I=1,M
 115      SUM13=((OCFS(I,ID1)-OBSMEAN)/SDM)*((OCFS(I,ID2)-
     &    SIMMEAN)/SDS)+SUM13


      OF1=SUM1
      OF2=SUM2
      OF3=SUM3
      OF4=SUM4
      OF5=SUM5
      OF6=SUM6
      OF7=SUM2/SUM10
      OF8=SUM4/SUM11
      OF9=SUM5/SUM8
      OF10=SUM6/SUM9
      AM=M
      OF11=(1./AM)*SUM13

      WRITE(6,95)
 95   FORMAT(1H0,10X,'------------------------------------------')
      WRITE(6,50)
 50   FORMAT(15X,' MEASURES OF FIT '//)
      WRITE(6,91)
 91   FORMAT(10X,'------------------------------------------')
      WRITE(6,51)OF1
 51   FORMAT(10X,'SUM OF ERRORS          ',F20.5)
      WRITE(6,52)OF2
 52   FORMAT(10X,'OLSQ                   ',F20.5)
      WRITE(6,53)OF3
 53   FORMAT(10X,'LOG LSQ                ',F20.5)
      WRITE(6,54)OF4
 54   FORMAT(10X,'RELATIVE ERROR         ',F20.5)
      WRITE(6,55)OF5
 55   FORMAT(10X,'ABS ERROR - DIFF       ',F20.5)
      WRITE(6,56)OF6
 56   FORMAT(10X,'REL ERROR - DIFF       ',F20.5)
      WRITE(6,57)OF7
 57   FORMAT(10X,'ABS ERROR/VAR         ',F20.5)
      WRITE(6,58)OF8
 58   FORMAT(10X,'REL ERROR/VAR         ',F20.5)
      WRITE(6,59)OF9
 59   FORMAT(10X,'ABS ERROR(diff)/VAR    ',F20.5)
      WRITE(6,60)OF10
 60   FORMAT(10X,'REL ERROR(diff)/VAR    ',F20.5)
      WRITE(6,61)OF11
 61   FORMAT(10X,'PEARSONS r             ',F20.5)
      WRITE(6,92)ESDEV
 92   FORMAT(10X,'ERR STANDARD DEV       ',F20.5)
      WRITE(6,93)PCTER
```

```
93    FORMAT(10X,'PEAK Q ERROR           ',F20.5)
      WRITE(6,96)
96    FORMAT(10X,'------------------------------------------')

      WRITE (6,98)
98    FORMAT (//10X,'NOTE:  All indicies are in metric units')

      IF (KCODE.EQ.0)THEN
        DO 9969 I=1,M
                OCFS(I,ID1)=OCFS(I,ID1)/.02832
9969            OCFS(I,ID2)=OCFS(I,ID2)/.02832
      ENDIF

      RETURN
C
      END
C
C
C ==========================================
C
      SUBROUTINE SEDT
C
C ==========================================

C     THIS SUBROUTINE COMPUTES THE SEDIMENT YIELD FOR A FLOOD

      COMMON/BLOCK2/OCFS(300,6),DATA(310),RAIN(300),ROIN(6),
     &IEND(6),DA(6),DT(6),PEAK(6),TIME,KCODE,ICODE

      ID=DATA(1)
      SOIL=DATA(2)
      CROP=DATA(3)
      CP=DATA(4)
      SL=DATA(5)
      WRITE(6,*)'** CHECK THIS IS CORRECT AREA',DA(ID)
      WRITE(6,*)'ESPECIALLY IF MULTIPLE ROUTING UTILIZED'
C     COMPUTE SEDIMENT YIELD
      X=ROIN(ID)*DA(ID)*53.333*PEAK(ID)
      SED=95.*X**.56*SOIL*CROP*CP*SL
      IF(ICODE.EQ.0)GO TO 5
      SED1=SED*0.9072
      WRITE(6,6)SED1
      GO TO 2
5     WRITE (6,3) SED
2     RETURN
3     FORMAT (10X, 'SEDIMENT YIELD = ', F10.1, ' TONS')
6     FORMAT(10X,"SEDIMENT YIELD=",F10.1,"METRIC TON")
      END
C
C
C ========================================
C
      BLOCK DATA
C
C ========================================

C     BLOCK DATA SUBPROGRAM UZED TO INITIALIZE ZALPHA,CTBLE,ITBLE
C     AND NCOMM.
```

```

      COMMON/BLOCK1/CTBLE(50,11),ITBLE(50,2),ZALPHA(20),
     &MAXNO,NCODE,ICC,NCOMM
      DATA ZALPHA/1H1,1H2,1H3,1H4,1H5,1H6,1H7,1H8,1H9,1H0,1H ,
     &1H*,1H.,1H,,1H-,1H ,1H ,1H ,1H ,1H /

      DATA NCOMM/15/

      DATA CTBLE/1HS,1HS,1HC,1HP,1HP,1HA,1HS,1HC,1HS,1HC,1HR,
     &1HR,1HE,1HS,1HF,35*1H ,
     &1HT,1HT,1HO,1HR,1HL,1HD,1HT,1HO,1HT,1HO,1HO,1HO,1HR,
     &1HE,1HI,35*1H ,
     &2HAR,2HOR,2HMP,2HIN,2HOT,2HD ,2HOR,2HMP,2HOR,2HMP,
     &2HUT,2HUT,2HRO,2HDI,2HNI,35*2H  ,
     &2HT ,2HE ,2HUT,2HT ,2H H,2HHY,2HE ,2HUT,2HE ,2HUT,
     &2HE ,2HE ,2HR ,2HME,2HSH,35*2H  ,
     &2H  ,2HHY,2HE ,2HHY,2HYD,2HD ,2HRA,2HE ,2HTR,2HE ,
     &2H  ,2HRE,2HAN,2HNT,2H  ,35*2H  ,
     &2H  ,2HD ,2HHY,2HD ,2H  ,2H  ,2HTI,2HRA,2HAV,2HTR,
     &2H  ,2HSE,2HAL,2H Y,2H  ,35*2H  ,
     &2H  ,2H  ,2HD ,2H  ,2H  ,2H  ,2HNG,2HTI,2HEL,2HAV,
     &2H  ,2HRV,2HYS,2HIE,2H  ,35*2H  ,
     &6*2H  ,2H C,2HNG,2H T,2HEL,2H  ,2HOI,2HIS,2HLD,36*2H  ,
     &6*2H  ,2HUR,2H C,2HIM,2H T,2H  ,2HR ,38*2H  ,
     &6*2H  ,2HVE,2HUR,2HE ,2HIM,40*2H  ,
     &7*2H  ,2HVE,2H  ,2HE ,40*2H  /

      DATA ITBLE/1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,35*1H ,
     &3,310,310,4,2,4,100,310,100,8,7,25,2,5,0,35*1H /
      END
```

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